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ABSTRACT

This guide is designed to assist teachers conducting a course to prepare students for entry-level employment in the residential wiring trade. Included in the guide are six instructional units and the following sections of information for teachers: guidelines in using the unit components; academic and workplace skills classifications and definitions; competency profile; instructional/task analysis; list of related academic and workplace skills; list of tools, equipment, and materials required to complete the assignment/job sheets; a 15-item reference list; and a glossary. The following topics are covered in the instructional units: blueprint reading and load calculations, rough-in, service, trim out and troubleshooting, load center charges, and "smart house" wiring. Each unit contains some or all of the following: objective sheet, suggested activities, assignment and written test answers, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, student supplements, assignment sheets, and job sheets (lists of criteria for evaluating student performance). (MN)

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MAVCC

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Second Edition

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Residential Wiring
Second Edition

Teacher Edition

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Foreword

Residential Wiring, ©1994, is a revision of MAVCC's 1988 wiring publication of the same name. It is the second in a series of three wiring publications and picks up where *Basic Wiring* ends and prepares the student for entry-level employment in the residential wiring trade. A new unit on SMART HOUSES has been added in this second edition.

Basic Wiring, ©1994, is the first publication in the wiring series and serves as the foundation for students enrolled in a wiring program. It is a prerequisite to either *Residential Wiring* or *Commercial and Industrial Wiring*. An applied math unit has been added in the second edition to reinforce computational skills needed in the wiring industry. This series of publications should provide the flexibility that instructors need to meet the individual needs of their students and the community.

Commercial and Industrial Wiring, ©1994, is the third publication in the wiring series and includes the additional technical knowledge and applications required for job entry in the commercial and industrial wiring trade.

MAVCC's wiring series was developed with the assistance of many individuals who have expertise in various areas of the wiring trade. Some of these individuals represent professional associations and industry. Their assistance and support is greatly appreciated. It should be emphasized that the student needs to be aware of professional trade associations and take an active part in them as much as possible. The professional trade associations, as well as vocational education, are an excellent avenue for continuing education within the electrical trade.

These instructional materials are designed not only for student use but also to assist the teacher in improving instruction. Every effort has been made to make these materials basic, readable, and usable. Teachers will need to develop instructional strategies for localizing, individualizing, and supplementing these materials.

Special attention should be given to the list of related academic and workplace skills in the introductory pages and to the teaching suggestions in each unit of instruction. These suggestions present academic skills being reinforced by the instructional materials and ways to increase reinforcement of workplace skills. By reinforcing basic skills, the teacher will assist students in becoming more productive workers.

As you use these instructional materials, we hope you will find they contribute to the quality of your program. If any problems occur or if you have suggestions for improvement, please call or write us.

Mervin Birdwell, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

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Use of Introductory Materials

Introductory materials are included in the teacher edition only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information such as the table of contents, foreword, and acknowledgements page, information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/ learning process.

2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.

3. **Instructional/task analysis**—Provides a quick review of contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.

4. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to related academic and workplace skills being reinforced. Skill areas reflected by skill groups, sub skills, and descriptions have been identified using *Workplace Basics: The Skills Employers Want*, developed by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

5. **Tools, equipment, and materials list**—Provides a comprehensive list of those items needed to successfully complete the assignment sheets and/or job sheets; assists administrator/teacher in determining program costs.

6. **Reference list**—Provides a comprehensive list of resources used in the development of this publication.

7. **Glossary of terms**—Provides a comprehensive list of terms and definitions found in Objective 1 of all units of instruction.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

Residential Wiring contains six units of instruction. Each instructional unit in a teacher edition includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, assignment sheets, student supplements, and job sheets.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Objective sheet (Color code: White)

Each unit of instruction is based on performance objectives which state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives which state the expected performance of each student after completion of the unit of instruction, and specific objectives which state what the student must do to reach the unit objective.

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested activities (Color code: Pink)

This component is included only in the teacher edition. The suggested activities assist teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teacher suggestions, and skill areas have been noted in bold. (A table of academic and workplace skills with accompanying definitions has been provided on page xv.) The teacher should read the suggested activities before teaching the units and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Instructions for evaluating student performance on the job sheets are also included in the suggested-activities section. Teachers should select and discuss with students the rating scale that will be used.

Assignment and written test answers (Color code: Pink)

Assignment-sheet answers and written-test answers are designed to assist the teacher in evaluation of student performances.

Written test (Color code: Yellow)

This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction. The test appears in the teacher edition only, but duplication is permitted for student use. If objectives have been added, deleted, or modified, appropriate changes should be made on the written test. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired.

Unit evaluation form (Color code: White)

This sheet provides teachers with a record of each students performance on a unit of instruction. It includes space for assignment sheet ratings, job sheet ratings, written test scores, and teacher comments. The unit evaluation form is included in the teacher edition only, but may be duplicated.

Use of This Publication

Teacher supplements (Color code: White)

This component is included only in the teacher edition. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher level materials to stretch the advanced student, with remedial information or practice to assist the less-advanced student, and with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

Transparency masters (Color code: White)

Transparencies are included in the teacher edition only and are used to direct the students' attention to the topic of discussion. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

Information sheet (Color code: Green)

The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Student supplements (Color code: White)

Student supplements are included in the student edition. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students will need in order to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment sheets or job sheets.

Assignment sheets (Color code: Tan)

Assignment sheets provide students with pencil and paper activities that give students the opportunity to make practical application of the knowledge in the information sheet. Criteria are provided to objectively evaluate student performance.

Job sheets (Color code: Blue)

The job sheets provide criteria to objectively evaluate student performance, a list of required equipment and materials, and a step-by-step procedure for performing a psychomotor skill. The teacher should discuss the equipment and materials available in the classroom and/or laboratory and demonstrate the procedure prior to having students practice procedure. When a student is ready to be evaluated, the teacher should follow instructions for evaluating student performance which may be found in the teacher edition.

Job sheets are an important segment of each unit. Job sheets provide potential employers with a picture of the skills being taught during training and the performances that might reasonably be expected from an individual who has had this training.

Disseminating material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder or folder for the current unit of study. This is convenient for students taking the material home to study. Upon completion, each unit is then placed in a larger binder. Some teachers prefer to store the material by unit in filing cabinets or boxes until needed.

For best results, provide student materials for each student. Student editions contain objective sheets, information sheets, student supplements, assignment sheets, and job sheets. Students should be allowed to take their materials home at the end of the course.

Academic and Workplace Skills
(Classifications and Definitions)

Skill Groups	Sub Skills	Definitions
Learning Skills	Learning to learn	Developing ability to apply knowledge to other situations; knowing how to learn.
Foundation Skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea or fact in written form in a clear, concise manner.
	Math	Applying computation skills such as reasoning, estimation, and problem solving as they are actually used on the job.
	Science	Applying knowledge learned through study or practice that is based on scientific principles as they relate to specific tasks.
Communication Skills	Listening	Listening for content, conversation, long-term contexts, emotional meaning, and directions.
	Oral communication	Communicating a thought, idea, or fact in spoken form in a clear, concise manner.
Adaptability Skills	Creative thinking	Using imagination to create something new—i.e. an idea, invention, work of art.
	Problem solving (critical thinking)	Recognizing and defining problems, inventing, and implementing solutions, and tracking and evaluating results.
Personal Management Skills	Self-esteem	Developing self-confidence and creating a positive self-image.
	Motivation/goal setting	Setting and meeting defined goals and objectives.
	Personal and career development	Emphasizing self-direction by establishing and implementing a plan.
Group Effectiveness Skills	Interpersonal relations	Developing ability to maintain positive relations with others.
	Negotiation	Resolving conflict between two or more individuals.
	Teamwork	Working together in a group to reach a common goal.
Influence Skills	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Leadership	Directing/influencing group in performance of a specific task; accepting responsibility for others.

Residential Wiring

Competency Profile

Name: ________________________________

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focus on a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Option A

Rating scale:
4 - Skilled - Can perform job with no additional training.
3 - Moderately Skilled - Has performed job during training program; limited additional training may be required.
2 - Limited Skill - Has performed job during training program; additional training is required to develop skill.
1 - Unskilled - Is familiar with process, but is unable to perform job.
0 - No Exposure - No information or practice provided during training program, complete training required.
NA - Non-applicable.

Option B

Yes - Can perform with no additional training
No - Is unable to perform satisfactorily

Unit 1: **Blueprint Reading and Load Calculations**

______1. Draw receptacle and lighting outlets on a floor plan.
______2. Determine general lighting loads.
______3. Determine small appliance and laundry loads.
______4. Determine total connected load plus total demand load of a dwelling.
______5. Locate required receptacle and lighting outlets on a house plan.
______6. ________________________________

______Written Test Score

Unit 2: **Rough-In**

______1. Locate receptacle switch, and lighting outlets along a floor line and the ceiling on a blueprint.
______2. Locate receptacle outlets along kitchen cabinets.
______3. Install a device box when given cabinet height and wall covering.
______4. Install a lighting outlet box when given ceiling covering thickness.
______5. Wire a switch controlled split-wired receptacle.
______6. Wire a receptacle fed from a lighting outlet through a single pole switch.
______7. Wire a receptacle fed from a lighting outlet through a three-way switch.

______8. Wire a four-way switching situation with the supply entering the lighting outlet box.
______9. Mount a fan box according to manufacturer's recommendations.
______10. Mount a fan box and switch in an existing dwelling according to manufacturer's recommendations.
______11. ______________________________

______Written Test Score

Unit 3: Service

______1. Calculate service size and minimum number of circuits.
______2. Install an overhead raceway with service entrance conductors to a meter base.
______3. Connect meter base assembly to load center or panel.
______4. Install an underground service (lateral) raceway with conductors to a meter base.
______5. ______________________________

______Written Test Score

Unit 4: Trim Out and Troubleshooting

______1. Install a duplex grounding type receptacle.
______2. Install a range or dryer receptacle.
______3. Install a multi-circuit split-wired duplex grounding type receptacle.
______4. Wire a receptacle fed from a lighting outlet through a single pole switch.
______5. Connect a supply cord to a free standing range.
______6. Install a fixed appliance equipped with a pigtail to a branch circuit.
______7. Install a fusible safety switch for an air-conditioning condenser.
______8. Troubleshoot an electrical system problem.
______9. ______________________________

______Written Test Score

Unit 5: Load Center Changes

______1. Replace an existing interior flush mount load center.
______2. Install a rainproof load center to supplement an existing interior load center.
______3. ______________________________

______Written Test Score

Competency Profile

Unit 6: **SMART HOUSE Wiring**

______1. Use Article 780 of the *National Electrical Code®* to answer questions related to SMART HOUSE wiring.

______2. ____

______Written Test Score

COMMENTS: ____

____

____

____

____

Evaluator: ______________________________ Date:____________________

*** Permission to duplicate this profile is granted.**

Residential Wiring

Instructional/Task Analysis

Related Information: What the Student Should Know	**Application: What the Student Should Be Able to Do**

Unit 1: Blueprint Reading and Load Calculations

1. Terms and definitions
2. Blueprint symbols
3. Electrical symbols
4. Types of lines
5. Information commonly found in blueprint specifications
6. Minimum requirements for residential outlets
7. Calculating circuit loads and voltage drop
8. Draw receptacle and lighting outlets of a floor plan
9. Determine general lighting loads
10. Determine small appliance and laundry loads
11. Determine total connected load plus total demand load of a dwelling
12. Locate required receptacle and lighting outlets on a house plan

Unit 2: Rough-In

1. Terms and definitions
2. Locations where at least one receptacle outlet is required
3. Planning techniques when placing boxes on plans
4. Accepted heights for boxes in various locations
5. Procedure for installing boxes in exterior walls
6. Box extensions for noncombustible and combustible wall surfaces
7. Common methods of finding room centers
8. Required outlets

Instructional/Task Analysis

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
Unit 2: (Cont.)	
9. Rules for electrical installations	10. Locate receptacle, switch, and lighting outlets along a floor line and the ceiling on a blueprint
	11. Locate receptacle outlets along kitchen cabinets
	12. Install a device box when given cabinet height and wall covering
	13. Install a lighting outlet box when given ceiling covering thickness
	14. Wire a switch controlled split-wired receptacle
	15. Wire a receptacle fed from a lighting outlet through a single pole switch
	16. Wire a receptacle fed from a lighting outlet through a three-way switch
	17. Wire a four-way switching situation with the supply entering the lighting outlet box
	18. Mount a fan box according to manufacturer's recommendations
	19. Mount a fan box and switch in an existing dwelling according to manufacturer's recommendations
Unit 3: Service	
1. Terms and definitions	
2. Clearances for service drop conductors	
3. Service disconnects	

Instructional/Task Analysis

Unit 3: (Cont.)

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
4. Facts that should be known before service installation is started	10. Calculate service size and minimum number of circuits
5. Parts of a service entrance	11. Install an overhead raceway with service entrance conductors to a meter base
6. Types of grounding electrodes	
7. Grounding electrode conductor installations and sizes	12. Connect meter base assembly to load center or panel
8. Short circuit protection at service equipment	13. Install an underground service (lateral) raceway with conductors to a meter base
9. Surge protection	

Unit 4: Trim Out and Troubleshooting

1. Terms and definitions
2. Common residential receptacle types and cover plates
3. Common residential switch types and cover plates
4. Common residential fixture locations
5. Appliance classifications
6. Requirements for appliance disconnect means
7. Grounding requirements for appliances
8. Parts of a duplex grounding type receptacle
9. Parts of an equipment grounding system
10. Steps for panel trim out

Instructional/Task Analysis

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
Unit 4: (Cont.)	
11. Troubleshooting procedures	12. Install a duplex grounding type receptacle
	13. Install a range or dryer receptacle
	14. Install a multi-circuit split-wired duplex grounding type receptacle
	15. Wire a receptacle fed from a lighting outlet through a single pole switch
	16. Connect a supply cord to a free standing range
	17. Install a fixed appliance equipped with a pigtail to a branch circuit
	18. Install a fusible safety switch for an air-conditioning condenser
	19. Troubleshoot an electrical system
Unit 5: Load Center Changes	
1. Terms and definitions	6. Replace an existing interior flush mount load center
2. Types of load centers	7. Install a rainproof load center to supplement an existing interior load center
3. Reasons for load center changes	
4. Ways to increase service size on an existing dwelling	
5. Procedures for changing existing service	
Unit 6: SMART HOUSE Wiring	
1. Terms and definitions	
2. Definition of a SMART HOUSE	
3. Operation of a SMART HOUSE	

Instructional/Task Analysis

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
Unit 6: (Cont.)	
4. Features of a SMART HOUSE 5. Blueprint symbols used in SMART HOUSE wiring 6. Two phases of SMART HOUSE wiring 7. Cables used in SMART HOUSE wiring 8. Types of outlets used in SMART HOUSEs 9. Components of a service center 10. Special tools used in SMART HOUSE wiring	11. Use Article 780 of the *National Electrical Code®* to answer questions related to SMART HOUSE wiring

Related Academic and Workplace Skills For *Residential Wiring*

Task	Skill Group	Sub Skill	Description
Unit 1: Blueprint Reading and Load Calculations			
Draw receptacle and lighting outlets on a floor plan (A.S. 1)	Foundation Skills	Reading	Uses standard occupational resource materials; analyzes and applies what has been read to specific task
Determine general lighting loads (A.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; draws conclusions from what is read
		Math	Applies computation skills as they are actually used on the job—multiplication
Determine small appliance and laundry loads (A.S. 3)	Foundation Skills	Reading	Uses standard occupational resource materials; draws conclusions from what is read
		Math	Applies computation skills as they are actually used on the job—multiplication
Determine total connected load plus total demand load of a dwelling (A.S. 4)	Foundation Skills	Reading	Uses standard occupational resource materials; draws conclusions from what is read
		Math	Applies computation skills as they are actually used on the job—addition, multiplication; calculates percentages
Locate required receptacle and lighting outlets on a house plan (A.S. 5)	Foundation Skills	Reading	Uses standard occupational resource materials; analyzes and applies what has been read to a specific task
Unit 2: Rough-In			
Locate receptacle, switch, and lighting outlets along a floor line and the ceiling on a blueprint (A.S. 1)	Foundation Skills	Reading	Uses standard occupational resource materials; analyzes and applies what has been read to specific task
Locate receptacle outlets along kitchen cabinets (A.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; analyzes and applies what has been read to specific task
Install a device box when given cabinet height and wall covering (J.S. 1)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; uses appropriate materials and techniques

Related Academic and Workplace Skills For *Residential Wiring*

Task	Skill Group	Sub Skill	Description
Unit 2: (Cont.)			
Install a lighting outlet box when given ceiling covering thickness (J.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Wire a switch controlled split-wired receptacle (J.S. 3)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Wire a receptacle fed from a lighting outlet through a single pole switch (J.S. 4)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Wire a receptacle fed from a lighting outlet through a three-way switch (J.S. 5)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Wire a four-way switching situation with the supply line entering the lighting outlet box (J.S. 6)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Mount a fan box according to manufacturer's instructions (J.S. 7)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques
		Math	Makes precision measurements using measuring device-rule
Mount a fan box and switch (in an existing dwelling) according to manufacturer's recommendations (J.S. 8)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques
		Math	Makes precision measurements using measuring device-rule

Related Academic and Workplace Skills For *Residential Wiring*

Task	Skill Group	Sub Skill	Description
Unit 3: Service			
Calculate service size and minimum number of circuits (A.S. 1)	Foundation Skills	Reading	Uses standard occupational resource materials; uses tables to obtain factual information; comprehends written specifications and applies them to a task
		Math	Applies computation skills as they are actually used on the job—addition, subtraction, multiplication, division; calculates percentages
Install an overhead raceway with service center entrance conductors to a meter base (J.S. 1)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Connect meter base assembly to load center or panel (J.S. 2)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Install an underground service (lateral) raceway with conductors to a meter base (J.S. 3)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Unit 4: Trim Out and Troubleshooting			
Install a duplex grounding type receptacle (J.S. 1)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; uses appropriate materials and techniques; reads measuring device to test equipment
Install a range or dryer receptacle (J.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques; reads measuring device to test equipment

Task	Skill Group	Sub Skill	Description
Unit 4: (Cont.)			
Install a multi-circuit split-wired duplex grounding type receptacle (J.S. 3)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques; reads measuring device to test equipment
Wire a receptacle fed from a lighting outlet through a single pole switch (J.S. 4)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques; reads measuring device to test equipment
Connect a supply cord to a free standing range (J.S. 5)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Install a fixed appliance equipped with a pigtail to a branch circuit (J.S. 6)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Install a fusible safety switch for an air-conditioning condenser(J.S. 7)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques
Troubleshoot an electrical system problem (J.S. 8)	Foundation Skills	Reading	Applies information and concepts derived from printed material; follows written directions
	Communication Skills	Listening	Listens for content
		Oral communication	Asks questions to obtain/clarify information
	Learning Skills	Learning to learn	Processes new information as related to workplace
	Adaptability Skills	Problem solving	Draws conclusions from observations and evaluates conditions and gives possible solutions

Related Academic and Workplace Skills
For *Residential Wiring*

Task	Skill Group	Sub Skill	Description
Unit 5: Load Center Changes			
Replace an existing interior flush mount load center (J.S. 1)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques; reads measuring device to test circuits
Install a rainproof load center to supplement an existing interior load center (J.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; comprehends written specifications and applies them to a task; uses appropriate materials and techniques; reads measuring device to test circuits
Unit 6: SMART HOUSE Wiring			
Use Article 780 of the *National Electrical Code* to answer questions related to SMART HOUSE wiring (A.S. 1)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed
		Writing	Presents answers in a clear and understandable form
	Adaptability Skills	Problem solving	Draws conclusions from what is read

Tools, Equipment, and Materials List

- Appliance cord
- Auxiliary lighting
- Awl
- Bar hanger
- Bulb, 120 volt
- Bushings
- Cable
- Cable clamp, ⅜″
- Cable connector
- Circuit tester
- Closed nipple
- Copper, #2, #4
- Device box
- Drill motor
- Drop cloth
- Duplex grounding type receptacle
- Electrical supply
- Electrician's hammer
- Extension cord
- Fasteners
- Feeder wire
- Fixed appliance with pigtail
- Flat blade screwdriver
- Folding rule with sliding scale
- Free standing range
- GFCI
- Hacksaw
- Hacksaw blade
- Incandescent bulb, 120 volt
- Keyhole saw
- Knockout cutter set
- Leather gloves, insulated
- Level
- Light socket
- Lineworker's pliers
- Load center, rainproof
- Locknuts
- Long nose pliers
- Meter base
- Mock up wall
- Nails, 16 penny
- Needle nose pliers
- Neon test light
- NM cable, 12-2-G or 14-2-G
- NMB cable, 12-3-G or 14-3-G
- Octagon box
- Pencil
- Plain tip screwdriver
- Plasterboard nails
- Pocket knife
- Polarity tester
- Portable GFCI
- PVC coupling
- PVC 90 degree elbow
- PVC male adapter
- Raceway
- Raintight fusible, rigid metal conduit
- Rigid nonmetallic tubing
- Rule
- Safety glasses
- Safety switch
- Screws
- Service connectors
- Service entrance cap
- Single pole switch
- Staples
- Stud wall
- Switch, three-way
- Switch, four-way
- Tapping screws, metal
- Tool pouch
- Voltmeter
- Volt-ohm-ammeter
- Wire connectors
- Wire strippers
- Wood bit, ½″ or larger
- Wood ladder

Residential Wiring

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Glossary

A

Air-conditioning condenser — Refrigeration equipment that sits outside a residential dwelling and is used to remove heat from refrigerant; usually contains a hermetically sealed compressor

Appliance — Utilization equipment, generally other than industrial, normally built in standardized sizes or types, which is installed or connected as a unit to perform one or more functions such as clothes washing, air conditioning, food mixing, or deep frying

Appliance branch circuit — A 120V branch circuit rated at 1500 VA (20 amps) supplying energy to one or more outlets to which appliances are to be connected

Applications bus (applications branch)—A single run of applications cable with all applications bus outlets; applications busses are terminated at the system controller connector board

Applications cable—A ribbon cable consisting of two #18 AWG conductors used for 12-VDC power, and six #24 AWG conductors used as low voltage control conductors

Applications outlet—A low voltage outlet for sensors, wall switches, and various devices that communicate over the SMART HOUSE network and require 120 volt DC; applications outlets are not active during the SMART-REDI phase

B

Backsplash — That portion of a wall behind the kitchen cabinet, starting at the countertop and ending at the bottom of the wall hung cabinets

Blueprint — Copy of the original detailed drawings of a structure

Blueprint lines — A set of conventional symbols to depict an object

Box center — Midpoint on a boxes vertical dimension

Box set out — Distance that the box extends past the stud

Branch circuit — The circuit that extends from the last overcurrent protection device to the outlets

C

Cable clamp — Piece of equipment used to secure cables

Circuit breaker — Automatic overcurrent device that trips on overloads or shorts and is resettable

Coaxial headend—A combination RF signal combiner/amplifier; receives signal from various inputs, i.e. VCR's, video cameras located inside the house; it distributes the signal throughout the house

Communications cable—A cable that consists of two coaxial cables and four pairs of telephone conductors

Control panel—The SMART user interface; includes visual display and input terminal

Convenience center—A multifunctional outlet including a branch cable tap and one or more of the following; duplex receptacle block, fixture block, dimmer block, hybrid cable terminator, or a telephone/coaxial outlet; may be in SMART version or SMART-REDI version

Cutout box — An enclosure designed for surface mounting and having swinging doors or covers secured directly to and telescoping with the walls of the box proper

D

Device — Unit of an electrical system which is intended to carry but not utilize electrical energy

Disconnecting means — A device or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply

Distribution interface unit (DIU)—A one to four splitter/combiner for two coaxial cables and eight telephone conductors in a SMART HOUSE communications cable

Duplex grounding receptacle — A single yoke device with two grounding type receptacles

Dwelling — One or more rooms used for eating, living, and sleeping with permanent provisions for cooking and sanitation

F

Feed through — The use of a box for splicing or rerouting conductors to get to another location

Feeder circuit — All circuit conductors between the service equipment or the source of a separately derived system and final branch circuit overcurrent device

Flush — Even with the surface

Full load amps (F.L.A.) — Amperage at which equipment is designed to operate

G

Grounding electrode conductor — Conductor used to connect the grounding electrode to the equipment grounding conductor and/or the grounding conductor of the circuit at the service

H

Habitable — Suitable for people to occupy or live in

Hybrid branch cable—A ribbon-type cable that consists of three #12 AWG conductors and six #24 AWG low voltage control wires

Hybrid branch circuit—Up to 200 feet of hybrid branch cable with as many as 30 nodes; operates from the load center and the system controller

I

Individual branch circuit — Branch circuit that supplies only one piece of utilization equipment

Input/output mode—Contains a branch slave chip and will allow conventional low voltage products such as relays and sensors to be operated by the system controller

L

Life sustaining medical equipment — Equipment necessary to keep patients alive

Lighting outlet — An outlet intended for the direct connection of a lampholder or light fixture

Line leg — Conductor that supplies electrical energy to a switch

Load — Utilization equipment that consumes power

Load center — A factory assembled metal cabinet consisting of fuses or circuit breakers for overcurrent protection of electrical wiring

M

Multiple receptacle — A single yoke device with two or more receptacles

N

Neutral — A current carrying conductor that is intentionally grounded to carry unbalanced load back to the source

O

Outage — Period during which no current is available to circuits in a residential dwelling

Overcurrent protection — Weak link in the circuit that limits the amperage to a specified amount

P

Pigtail — Splicing technique that leaves an accessible conductor for termination at a device, load, or grounding terminal

Poles — Current carrying conductors, both grounded and ungrounded, on a receptacle, switch, or overcurrent device

Premises wiring — The interior and exterior wiring including power, lighting, control and signal circuits together with associated hardware, fittings, and wiring devices

R

Receptacle connecting fin — Detachable design feature that makes terminals common connections

Receptacle outlets — An outlet where one or more receptacles are installed

Roof flashing — Protective equipment used where the mast emerges from the roof or eave to seal around the raceway and protect against water damage

Room center — Point in a room that is equal distance from parallel walls

S

Service — The conductors and equipment for delivering energy from the supply system to the wiring system of the premise being served

Glossary

Service cable — Service conductors made up in the form of a cable

Service center—Location of all electrical and communications distribution controllers

Service conductors — Supply conductors that extend from the street main or from transformers to the service equipment of the premises to be supplied

Service drop — Power conductors coming into building from power company

Service entrance — The conductors and equipment for delivering electricity from the supply system to the wiring system of the premises served

Service entrance conductors, overhead system — Service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop

Service entrance conductors, underground system — Service conductors between the terminals of the service equipment and the point of connection to the service lateral

Service equipment — Necessary equipment, usually consisting of a circuit breaker or fuses and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply

Service lateral — Underground service conductors between the street main, including any risers at a pole or other structure or from transformers and the first point of connection to the service entrance conductors in a terminal box or meter or other enclosure with adequate space inside or outside the building wall

Service mast — That portion of the service raceway that extends through a roof or eave

Service raceway — Raceway that encloses the service entrance conductors

Short circuit — Unintentional contact of a conductor

Single receptacle — A single contact device with no other contact device on the same yoke

SMART appliance—An appliance that is capable of communicating with the system controller

SMART-REDI—Term that refers to SMART HOUSE products that are incapable of communicating with the system controller

Specifications — A detailed set of written instructions which explain the drawing and become part of the contract

Split-wired receptacle — Receptacle that has had a connecting fin removed for remote control or separate circuit connections

Strap or yoke — Metal strip containing one or more devices

Switch — Device used to open or transfer circuit direction

Switch leg — Conductor that carries electrical energy from the switch to the load

Switch loop — Conductors between light and switch when supply enters the light

Switch/sensor outlet—A low voltage wall switch outlet

Symbol — An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

System controller—Referred to as the "brain" of the system; it manages all SMART HOUSE system functions

T

Telephone gateway—Permits homeowners and service providers to control the SMART HOUSE or request data by a touch-tone phone; usually includes a voice mail system and intercom system

Terminal — Point of attachment for conductors

Tile cap — Final tile in a ceramic backsplash when the tile is terminated at some point up the wall

Traveler — Transfer conductors in a switching situation; they are used between 3-ways and 4-ways

Trim out — Final stage in a residential wiring project; involves devices and plates, connecting and securing equipment, hanging fixture, and testing the system

Troubleshooting — The systematic diagnosis of a malfunction

V

Volt ampere — Voltage multiplied times amperage

Voltage drop — A reduction in available voltage at the end of a circuit

W

Wires — Current carrying conductors and grounding conductors

Blueprint Reading and Load Calculations
Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able to interpret blueprint drawings and perform load calculations from the information provided in blueprint darwings and specifications. The student should demonstrate these competencies by completing the assignment sheet and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to blueprint reading and load calculations with their correct definitions.
2. Identify blueprint symbols used in residential drawings.
3. Match electrical symbols with their correct descriptions.
4. Match types of lines with their pictures and descriptions.
5. List kinds of information commonly found in blueprint specifications.
6. Select true statements concerning minimum requirements for residential outlets.
7. Calculate circuit loads and voltage drop of a dwelling.
8. Draw receptacle and lighting outlets on a floor plan. (Assignment Sheet 1)
9. Determine general lighting loads. (Assignment Sheet 2)
10. Determine small appliance and laundry loads. (Assignment Sheet 3)
11. Determine total connected load plus total demand load of a dwelling. (Assignment Sheet 4)
12. Locate required receptacle and lighting outlets on a house plan. (Assignment Sheet 5)

Blueprint Reading and Load Calculations
Unit 1

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Obtain various resources such as films, videotapes, and software to supplement instruction of this unit.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Record assignment sheet and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Collect and distribute to the class a number of blueprint and specification plans from local contractors. Have students practice interpreting the symbols on the plans. As students progress through instruction, they can also perform load calculations on these plans. Skill areas: **math and problem solving**.

2. Contact a local contractor and invite her/him to class to discuss how to read blueprints and why they are important on the job. Have students prepare questions in writing beforehand and provide to speaker so that she/he will come prepared to respond to those questions when asked by students. Provide students with the compiled list of questions so that they may record the answers for future use. Skill areas: **writing, oral communication, and listening**.

3. Invite a local representative of the electrical inspection authority to visit the class to discuss the local code restrictions and how they affect the load calculations derived from blueprint specification plans. Have students review local code requirements and prepare questions they would like to ask. Provide students with list of questions so that they can record the answers for future use. Skill areas: **writing, oral communication, and listening**.

4. Have the students organize into separate groups and have each group design and draw to scale, a room or section of a house plan. Skill areas: **oral communication, listening, creative thinking, teamwork, math, and interpersonal relations**.

   Example: Group 1 will design and draw the kitchen dining room area of the house plan complete with symbols and dimensions. Group 2 will design and draw the master bedroom and master bath area. Group 3 will design and draw the living room and garage area. All groups should draw their areas to scale and provide necessary symbols and specifications. A completed drawing may then be assembled and load calculations made from the composite drawing and specifications.

5. Make copies of Teacher Supplement 1 to distribute to class following their completion of Assignment Sheet 5. This supplement serves as the answer sheet to the assignment, and students can evaluate their performance. Skill area: **problem solving**.

6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.

Suggested Activities

Resources Used in Developing This Unit

1. Gebert, Kenneth L. *Blueprint Reading*, 9th ed. Alsip, IL: American Technical Publishers, Inc., 1983.
2. *1993 National Electrical Code®*. Quincy, MA: National Fire Protection Association, 1992.

   Note: Copies of the 1993 *NEC* may be obtained from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269 or the International Association of Electrical Inspectors, 901 Waterfall Way, Suite 602, Richardson, TX 75080-7702.
3. Taylor, Mark. *Residential Wiring*. Revised. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

Suggested Supplemental Resources

Publications

1. Mullin, Ray C. *Electrical Wiring: Residential*, 11th ed. Albany, NY: Delmar Publishers, Inc., 1993.
2. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers Inc., 1993.

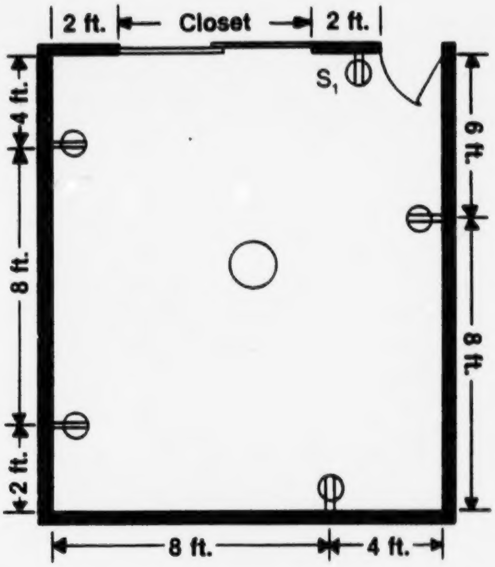
Instructions for Evaluating Student Performance

Assignment Sheet—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Blueprint Reading and Load Calculations
Unit 1

Answers to Assignment Sheets

Assignment Sheet 1



Note: This answer represents one possible solution.

Assignment Sheet 2

1.	3200 sq. ft. × 3VA =	9600VA
2.	2750 sq. ft. × 3VA =	8250VA
3.	4100 sq. ft.	24 ft.
	- 480 sq. ft. garage	× 20 ft.
	3620 sq. ft.	480 sq. ft. garage
	3620 sq. ft. × 3VA =	10,860VA

Assignment Sheet 3

1.	Small appliance circuits	2 circuits x 1500VA = 3000 VA
	Laundry circuits	1 circuit x 1500VA = 1500 VA
	Total small appliance and laundry loads	3 circuits x 1500VA = 4500 VA
2.	Small appliance circuits	4 circuits x 1500VA = 6000 VA
	Laundry circuits	1 circuit x 1500VA = 1500 VA
	Total small appliance and laundry loads	5 circuits x 1500VA = 7500 VA

Answers to Assignment Sheets

Assignment Sheet 4

Step #1	2400 sq. ft. x 3VA	=	7,200 VA
Step #2	2 small appliance circuits x 1500VA	=	3,000 VA
Step #3	1 laundry circuit x 1500VA	=	1,500 VA
	Total connected load	=	11,700 VA
Step #4			
	1st 3000 x 100%		3,000 VA
	Remaining 8700 x 35%		3,045 VA
	Total demand load	=	6,045 VA

Assignment Sheet 5—See Teacher Supplement 1 for detailed outlet layout. This assignment may be evaluated by either the instructor or student. (See Teaching Suggestion 5.)

Blueprint Reading and Load Calculations
Unit 1

Answers to Written Test

1. a. 2
   b. 4
   c. 6
   d. 9
   e. 11
   f. 1
   g. 7
   h. 5
   i. 10
   j. 3
   k. 8

2. a. Plumbing
   1) Showers
   2) Built-in bathtub
   3) Built-in lavatories
   4) Laundry tubs
   5) Water heater
   6) Single bowl sink
   7) Double bowl sink
   8) Shower heads
   9) Furnace

   b. Appliances
   1) Refrigerator
   2) Dishwasher (freestanding or built-in)
   3) Drop-in range
   4) Free standing range
   5) Built-in oven
   6) Surface cook top

   c. Structural symbols
   1) Exterior door in wood frame wall
   2) Exterior sliding door in wood frame wall
   3) Exterior door in masonry veneer wall
   4) Exterior sliding door in masonry veneer wall
   5) Interior hinged door
   6) Interior pocket door
   7) Single window in frame wall
   8) Multiple windows in frame wall
   9) Double hung window in frame wall

Answers to Written Test

3.	a.	3	h.	22	o.	16	v.	14
	b.	15	i.	20	p.	28	w.	19
	c.	2	j.	8	q.	25	x.	27
	d.	10	k.	1	r.	11	y.	13
	e.	21	l.	4	s.	7	z.	18
	f.	12	m.	5	t.	26	aa.	6
	g.	17	n.	23	u.	24	bb.	9

4.	a.	3	e.	6
	b.	5	f.	2
	c.	4	g.	1
	d.	7		

5. Any five of the following:

   a. Sizes
   b. Types and quality of building materials
   c. Methods of construction
   d. Material lists
   e. Owner's name and address
   f. Contractor's name and address
   g. Location of new structure
   h. Completion date
   i. Contractor's bid
   j. Guarantees
   k. Blueprint number

6. b, c

7.	a.	2,100	e.	3	i.	2,730
	b.	6,300	f.	6,300	j.	5,730
	c.	6,300	g.	10,800	k.	13,730
	d.	54.8	h.	10,800	l.	5.095

Blueprint Reading and Load Calculations
Unit 1

Written Test

Name ____ Score ________________

1. Match the terms on the right with their correct definitions.

______a. A set of conventional symbols to depict an object

______b. One or more rooms used for eating, living, and sleeping with permanent provisions for cooking and sanitation

______c. An outlet intended for the direct connection of a lampholder or light fixture

______d. A detailed set of written instructions which explains the drawing and becomes part of the contract

______e. A reduction in available voltage at the end of a circuit

______f. Copy of the original detailed drawings of a structure

______g. An outlet where one or more receptacles are installed

______h. All circuit conductors between the service equipment or the source of a separately derived system and final branch circuit overcurrent device

______i. An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

______j. The circuit that extends from the last overcurrent protection device to the outlets

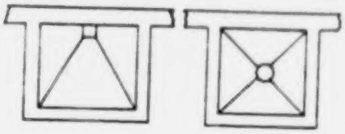
______k. The conductors and equipment for delivering electricity from the supply system to the wiring system of the premises served

1. Blueprint
2. Blueprint lines
3. Branch circuit
4. Dwelling
5. Feeder circuit
6. Lighting outlet
7. Receptacle outlet
8. Service entrance
9. Specification
10. Symbol
11. Voltage drop

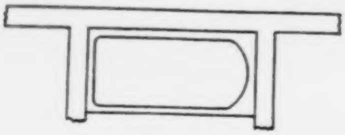
Written Test

2. Identify blueprint symbols used in residential drawings.

   a. Plumbing



1) ______________________________



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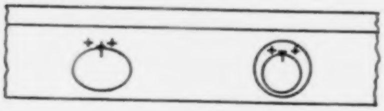

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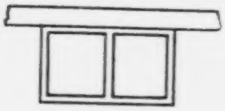
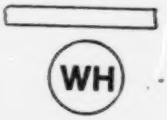
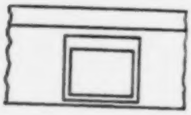


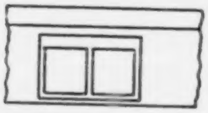
4) ______________________________



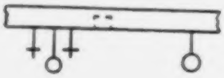
5) ______________________________



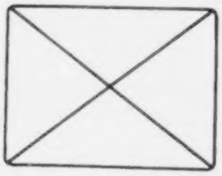
6) ______________________________



7) ______________________________



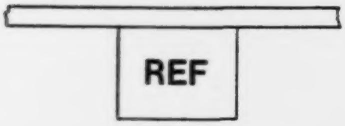
8) ______________________________



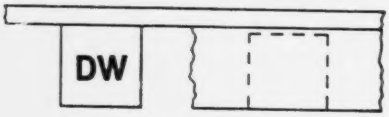
9) ______________________________

Written Test

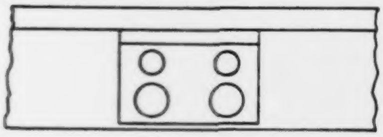
b. Appliances



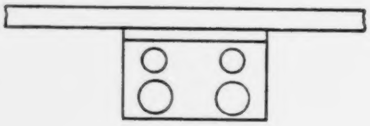
1) ______________________________



2) ______________________________



3) ______________________________



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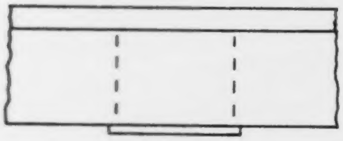

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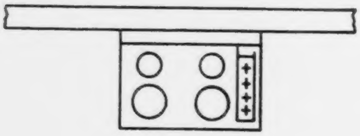
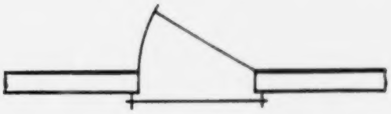


6) ______________________________

Written Test

c. Structural symbols



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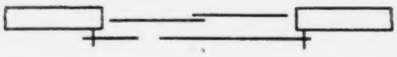

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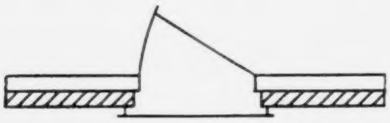

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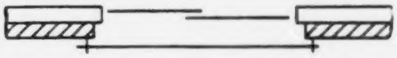

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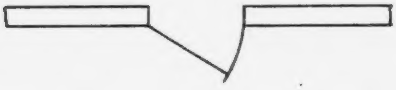

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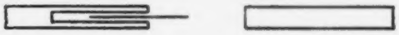

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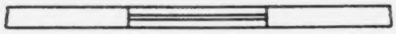

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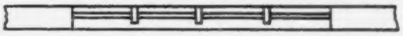

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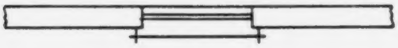


9) ______________________________

Written Test

3. Match the electrical symbols on the right with their correct descriptions.

______a. Ceiling outlet

______b. Range outlet

______c. Double pole switch

______d. Fluorescent fixture

______e. Lighting panel

______f. Branch circuit; exposed

______g. Duplex receptacle

______h. Ground

______i. Floor outlet

______j. Momentary contact switch

______k. Power panel

______l. Four-way switch

______m. Dimmer switch

______n. 240V, 3w, 2p receptacle

______o. Switch and convenience outlet

______p. Branch circuit; concealed in ceiling or wall

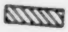
______q. Fuse

______r. Junction box

______s. Switch and pilot light

______t. Feeders

______u. Circuit breaker

1. 

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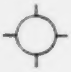
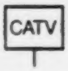
3. 

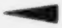
4. S_4

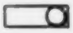
5. S_D

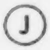
6. 

7. Sp

8. S_{mc}

9. 

10. 

11. 

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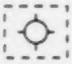
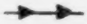
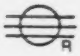
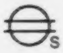
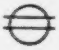
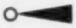
13. 

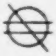
14. 

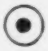
15. 

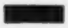
16. 

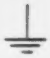
17. 

18. 

19. 

20. 

21. 

22. 

Written Test

______v. Home run to panel board

______w. 120/240, 1ϕ combination receptacle

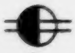
______x. Thermostat

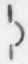
______y. Recessed incandescent

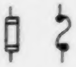
______z. Electronic smoke detector

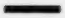
______aa. Cable TV outlet

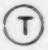
______bb. Phone outlet

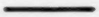
23. 

24. 

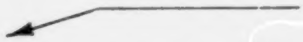
25. 

26. 

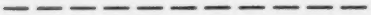
27. 

28. 

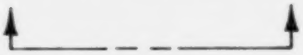
4. Match the types of lines on the right with their pictures and descriptions.

______a. 

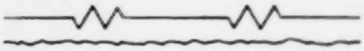
Used to connect a note or dimension to a part of the building

______b. 

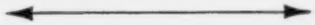
Short dashes used to show lines that are not visible from that view

______c. 

Heavy lines consiting of a series of one long and two short dashes with arrows at each end pointing away from the area that is cut away for the purpose of sectioning

______d. 

Used when an area cannot or should not be drawn entirely

______e. 

Thin unbroken lines which building dimensions are placed upon

1. Object lines
2. Center lines
3. Leaders
4. Cutting-plane lines
5. Hidden lines
6. Dimension lines
7. Break lines

______f. —— – ———— – ——

A series of short and long dashes used to designate the center of doors, windows, and circles and to provide a reference point for dimensioning

______g. ————————

Show the main outline of the building including exterior walls, interior partitions, porches, patios, driveways, and interior walls; these lines should be the outstanding lines on a drawing

5. List five kinds of information commonly found in blueprint specifications.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

6. Select true statements concerning minimum requirements for residential outlets by placing an "X" in the blank preceding the true statements.

______a. Receptacles — Installed so that no point along the floor line in any wall space is more than 4 feet from an outlet

______b. Switches — Located so that they may be operated from a readily accessible place

______c. Lighting — At least one wall switch controlled lighting outlet shall be installed in every habitable room, hall, stairway, attached garage, bathroom, and outdoor entrance to a residence

Written Test

7. Calculate circuit loads and voltage drop for the example below.

Dwelling has a floor space of 2,100 square feet. It also has an 11 kw electric range.

General lighting load
a.____________ sq. ft. × 3 watts per sq. ft. = b.____________

Minimum number of branch circuits
General lighting load c.____________ ÷ 115 = d.____________ ÷ 20 = e.____________ or number of general lighting circuits

Note: This number always rounds to next whole number if a fraction appears.

Small appliance load: Two 2-wire 20 ampere circuits
Laundry load: One 2-wire 20 ampere circuit

Minimum size feeders required
Computed load

General lighting	f.____________	watts
Small appliance	+3,000	watts
Laundry	+1,500	watts
Total (without range)	g.____________	watts
3,000 watts at 100% =	3,000	watts
Total (without range) h.____________ –		
3,000 = ____________ watts × 35% =	i.____________	watts
Net computed load (without range)	j.____________	watts
Range load	8,000	watts
Net computed load (with range)	k.____________	watts

A branch circuit conductor with a resistance of 1.93 ohm per mft. is installed at a length of 110 ft. This circuit has a load current of 12 amps. Calculate the voltage drop for this circuit.

l.____________

*Permission to duplicate this test is granted.

Blueprint Reading and Load Calculations
Unit 1

Unit Evaluation Form

Student Name ______________________ Unit Rating ________

Assignment Sheet 1—Draw Receptacle and Lighting Outlets on a Floor Plan Rating ______

Comments: ______________________

____

Assignment Sheet 2—Determine General Lighting Loads Rating ______

Comments: ______________________

____

Assignment Sheet 3—Determine Small Appliance and Laundry Loads Rating ______

Comments: ______________________

____

Assignment Sheet 4—Determine Total Connected Load Plus Total Demand Load of a Dwelling Rating ______

Comments: ______________________

____

Assignment Sheet 5—Locate Required Receptacle and Lighting Outlets on a House Rating ______

Comments: ______________________

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

*Permission to duplicate this form is granted.

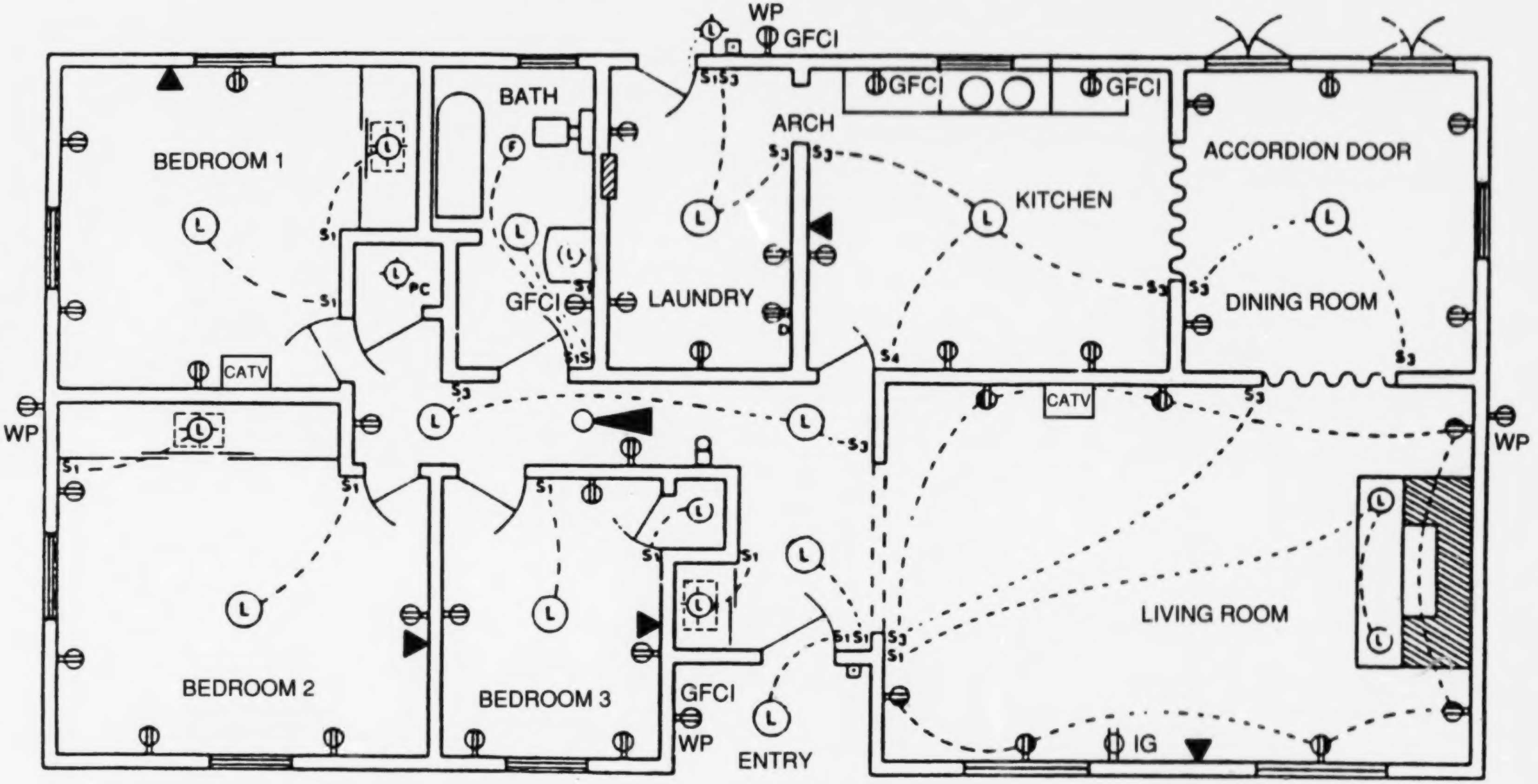
Blueprint Reading and Load Calculations
Unit 1

Teacher Supplement 1—Electrical Floor Plan

Note: Floor plan appears on back of this page.

***Permission to duplicate this plan is granted.**

Residential Wiring, Unit 1
Teacher Page 20


WP
GFCI
BEDROOM 1
BATH
ARCH
KITCHEN
GFCI
GFCI
ACCORDION DOOR
DINING ROOM
LAUNDRY
GFCI
PC
CATV
CATV
WP
WP
LIVING ROOM
BEDROOM 2
BEDROOM 3
GFCI
WP
ENTRY
IG

Electrical Floor Plan

Scale 1/8" = 1'

Blueprint Reading and Load Calculations
Unit 1

Information Sheet

1. **Terms and definitions**

   a. **Blueprint** — Copy of the original detailed drawings of a structure

   b. **Blueprint lines** — A set of conventional symbols to depict an object

   c. **Branch circuit** — The circuit that extends from the last overcurrent protection device to the outlets

   d. **Dwelling** — One or more rooms used for eating, living, and sleeping with permanent provisions for cooking and sanitation

   e. **Feeder circuit** — All circuit conductors between the service equipment or the source of a separately derived system and final branch circuit overcurrent device

      Note: This circuit originates at the service equipment and extends to the subpanel.

   f. **Lighting outlet** — An outlet intended for the direct connection of a lampholder or light fixture

   g. **Receptacle outlet** — An outlet where one or more receptacles are installed

   h. **Service entrance** — The conductors and equipment for delivering electricity from the supply system to the wiring system of the premises served

   i. **Specifications** — A detailed set of written instructions which explain the drawing and become part of the contract

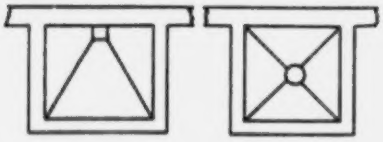
   j. **Symbol** — An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

   k. **Voltage drop** — A reduction in available voltage at the end of a circuit

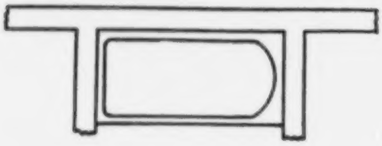
2. Blueprint symbols used in residential drawings

a. Plumbing

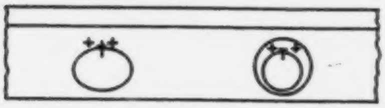
- Showers



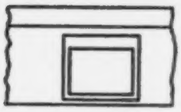
- Built-in bathtub



- Built-in lavatories

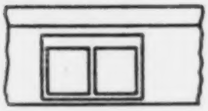


- Single bowl sink

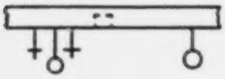


Information Sheet

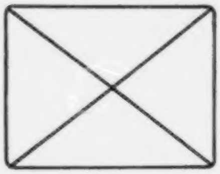
- Double bowl sink



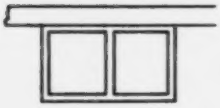
- Shower heads



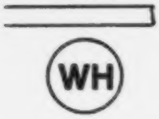
- Furnace (designate fuel and capacity)



- Laundry tubs



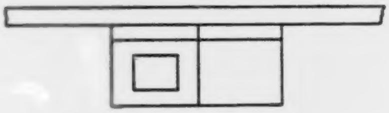
- Water heater (designate capacity and fuel)



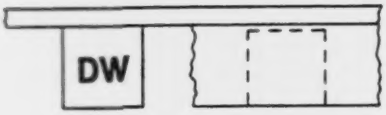
Information Sheet

b. Appliances

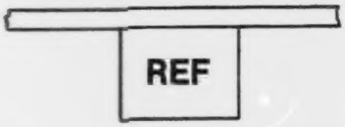
- Washer and dryer



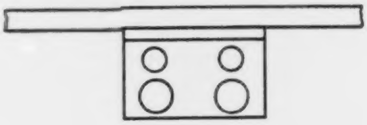
- Freestanding and built-in dishwashers



- Refrigerator

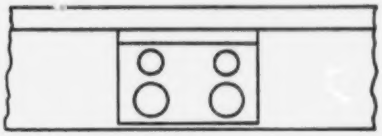


- Freestanding range

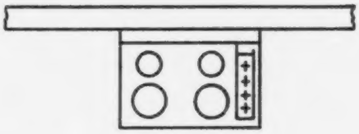


Information Sheet

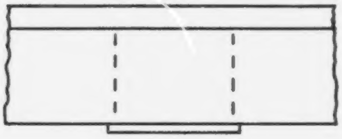
- Drop-in range



- Surface cook top

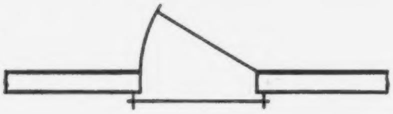


- Built-in oven

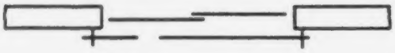


c. Structural symbols

- Plan view of exterior door in wood frame wall

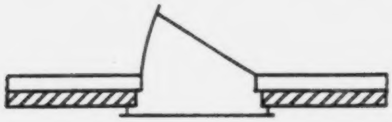


- Plan view of exterior sliding door in wood frame wall

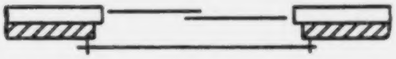


Information Sheet

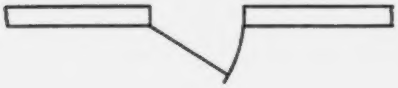
- Plan view of exterior door in masonry veneer wall



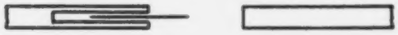
- Plan view of exterior sliding door in masonry veneer wall



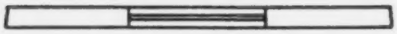
- Plan view of interior hinged door



- Plan view of interior pocket door

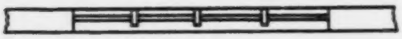


- Single window in frame wall

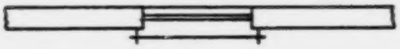


Information Sheet

- Multiple windows in frame wall

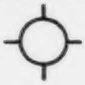


- Plan view of double hung window in frame wall

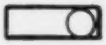


3. Electrical symbols

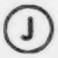
a. Convenience outlets



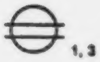
Ceiling outlet



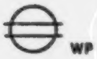
Fluorescent fixture



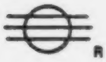
Junction box



Convenience outlet other than duplex
1=single, 3=triplex, etc.

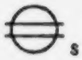
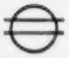
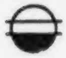
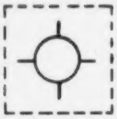
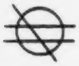
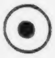
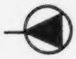
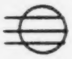
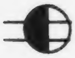
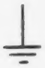
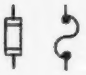
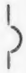


Weatherproof convenience outlet



Range outlet

Information Sheet

	Switch and convenience outlet
	Duplex receptacle
	Duplex receptacle split wired
	Recessed incandescent
	120/240, 1ϕ combination receptacle
	Floor outlet (attach additional symbol for recept. tel., etc.)
	Special outlet—as noted
	240V, 4W, 3P receptacle—amps as noted
	240V, 3W, 2P receptacle—amps as noted
	Ground
	Fuse
	Circuit breaker

Information Sheet

b. Switch outlets

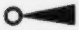
S	Single pole switch
S_2	Double pole switch
S_3	Three-way switch
S_4	Four-way switch
S_D	Dimmer switch
S_K	Key operated switch
S_P	Switch and pilot light
S_{MC}	Momentary contact switch
Ⓣ	Thermostat
Ⓗ	Humidistat

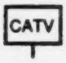
c. Panels, circuits, and miscellaneous

▬	Lighting panel
▨	Power panel
——	Branch circuit; concealed in ceiling or wall
—·—	Branch circuit; concealed in floor
-----	Branch circuit; exposed
→→	Home run to panel board; indicate number of circuits by number of arrows
━━	Feeders

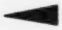
Information Sheet

d. Special symbols


Electronic smoke detector



Cable TV outlet


Phone outlet

4. Types of lines

a. Object lines — (————————) — Show the main outlines of the building including exterior walls, interior partitions, porches, patios, driveways, and interior walls; these lines should be the outstanding lines on a drawing

b. Dimension lines — (◄————————►) — Thin unbroken lines which building dimensions are placed upon

c. Extension lines — (————————) — Extend, but do not touch the object lines and permit dimension lines to be drawn between them

d. Hidden lines — (— — — — — —) — Short dashes used to show lines that are not visible from that view

e. Center lines — (– – ———— – –) — A series of short and long dashes used to designate the center of doors, windows, and circles and to provide a reference point for dimensioning

f. Break lines — (–∧∧–———–∧∧–) — Used when an area cannot or should not be drawn entirely

g. Leaders — (◄⁄——) — Used to connect a note or dimension to a part of the building

h. Cutting plane lines — (↑——— – – ———↑) — Heavy lines consisting of a series of one long and two short dashes with arrows at each end pointing away from the area that is cut away for the purpose of sectioning

Information Sheet

5. **Information commonly found in blueprint specifications**
   - a. Sizes
   - b. Types and quality of building materials
   - c. Methods of construction
   - d. Material lists

     Note: This can include electrical lists as supplied by the electrical contractor in bids to the general contractor.
   - e. Owner's name and address
   - f. Contractor's name and address
   - g. Location of new structure
   - h. Completion date
   - i. Contractor's bid
   - j. Guarantees
   - k. Blueprint number

6. **Minimum requirements for residential outlets**
   - a. Receptacles — Installed so that no point along the floor lines in any wall space is more than 6 feet from an outlet
   - b. Switches — Located so that they may be operated from a readily accessible place

     Note: Install opposite hinged side of door. Other minimum requirements for switches are covered in *NEC* Art: 380.
   - c. Lighting — At least one wall switch controlled lighting outlet shall be installed in every habitable room, hall, stairway, attached garage, bathroom, and outdoor entrance to a residence and at least one wall switch controlled light at point of entry to attics, under crawl spaces, basements, when this area is used for storage or containing equipment requiring service

Information Sheet

7. Calculating circuit loads and voltage drop of a dwelling

a. Branch circuits — All branch circuit loads of a dwelling may be grouped into one of three categories: (1) general lighting load, (2) small appliance and laundry load, and (3) special appliance load.

- General lighting load — To determine the general lighting load, multiply 3 volt amps (watts) times the total square foot area of the dwelling unit.

  Note: *NEC* Art: 220-3(b) Table lists the unit load required per square foot.

- Small appliance and laundry load — The small appliance and laundry loads are figured at 1,500 volt-amps (watts) for each two wire circuit.

  Note: *NEC* Art: 220-16 and 220-4 list requirements for small appliance and laundry circuits.

- Special appliance load — The special appliance loads are determined by the kilowatt rating listed on the nameplate.

  Note: *NEC* Art: 220-3 and 220-10(a) list requirements for special appliance loads.

b. Feeder circuits (subpanels) — The computed load for the feeders shall not be less than the sum of the loads on the branch circuits supplied.

Note: *NEC* Art: 220-10 covers feeder calculations.

c. Total load (service) — All loads in a dwelling are not used simultaneously or for extended periods of time. The application of demand factors will produce lower total demand loads. Lower demand loads require small service entrance conductors, resulting in less material cost for the job.

Note: Demand factors for dwelling loads are listed in *NEC* Art's: 220-11 (general lighting and receptacle load), 220-17 (fixed appliance load), 220-18 (dryer load), and 220-19 (range load).

d. Voltage drop — The formula for calculating voltage drop is,

$$VD = \frac{2 \times L \times R \times I}{CM}$$

VD = Voltage Drop

L = One way length of circuit in feet

R = Conductor resistance in ohms per 1000 feet

Note: See Chapter 9, Table 8 of the *NEC*.

I = Load current (amperes)

CM = Conductor area in circular mils

Blueprint Reading and Load Calculations
Unit 1

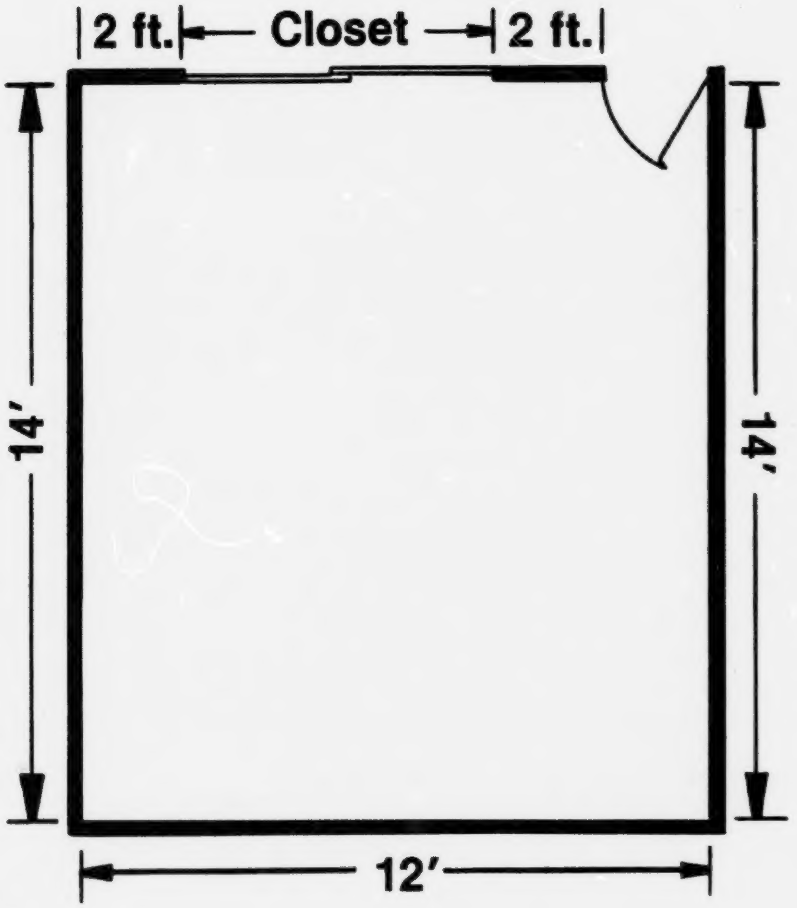
Assignment Sheet 1—Draw Receptacle and Lighting Outlets on a Floor Plan

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
NEC articles referenced to locate outlets	_____
Outlets placed in correct locations on drawing	_____
Appropriate symbols used	_____

Directions: Using electrical symbols, draw locations of receptacle outlets and lighting outlets for the floor plan on the back of this page. Refer to *NEC* Art: 210-8, 210-52, and 410-56-58 for minimum spacing and location.

Assignment Sheet 1


2 ft.
Closet
2 ft.
14′
14′
12′

Blueprint Reading and Load Calculations
Unit 1

Assignment Sheet 2—Determine General Lighting Loads

Name ______________________ Overall Rating ________

Evaluation criteria	Rating
General lighting load requirements given	____
Computations shown for each problem	____
Correct answers given	____

Directions: List the general lighting loads for the following dwellings. Use *NEC* Art: 220-3(b) to determine general lighting load minimum requirements. Show all computations in space provided.

1. 3200 sq. ft. with no garage. ________

2. 2750 sq. ft. with no garage. ________

Assignment Sheet 2

3. 4100 sq. ft. including a 20 ft. x 24 ft. garage. ____________

Blueprint Reading and Load Calculations
Unit 1

Assignment Sheet 3—Determine Small Appliance and Laundry Loads

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Used *NEC* to determine minimum requirements	_____
Computations shown for each problem	_____
Correct answers given	_____

Directions: Calculate the small appliance and laundry loads for the dwellings below. Use *NEC* Art's: 220-4(a), 220-4(b), 220-16(b), and 220-16(c) to determine minimum requirements. Show all computations in space provided.

1. A single family dwelling with one kitchen area and one laundry area. The specifications call for minimum circuits.

2. A single family dwelling with one kitchen area and one laundry area. The specifications call for four circuits in the kitchen area and one circuit in the laundry area.

Blueprint Reading and Load Calculations
Unit 1

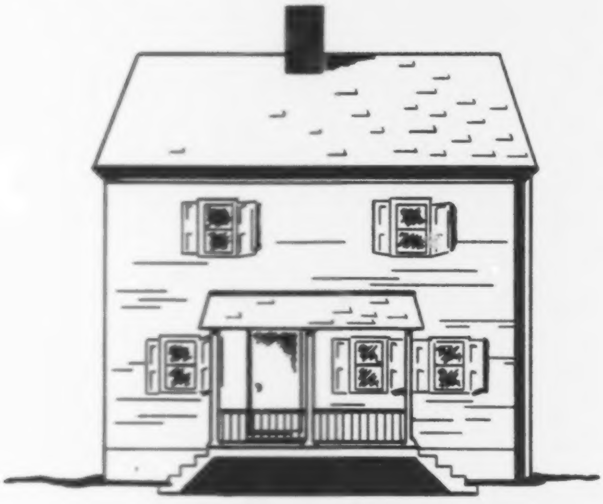
Assignment Sheet 4—Determine Total Connected Load Plus Total Demand Load of a Dwelling

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Calculated total connected load accurately	_____
Determined total demand load accurately	_____

Directions: Calculate the total connected load for the dwelling described below. Next apply appropriate demand factors to determine the total demand load.

Note: *NEC* Art: 220-3(b) Table will provide proper demand percentage information.



2400 Sq. Ft. Dwelling

Dwelling has two small appliance circuits and one laundry circuit.

Assignment Sheet 4

Step #1 2400 sq. ft. ____________ VA

Step #2 2 small appliance circuits ____________ VA

Step #3 1 laundry circuit ____________ VA

Total connected load ____________ VA

Step #4 *NEC* Table 220-3(b)

x % ____________ VA

x % ____________ VA

Total demand load ____________ VA

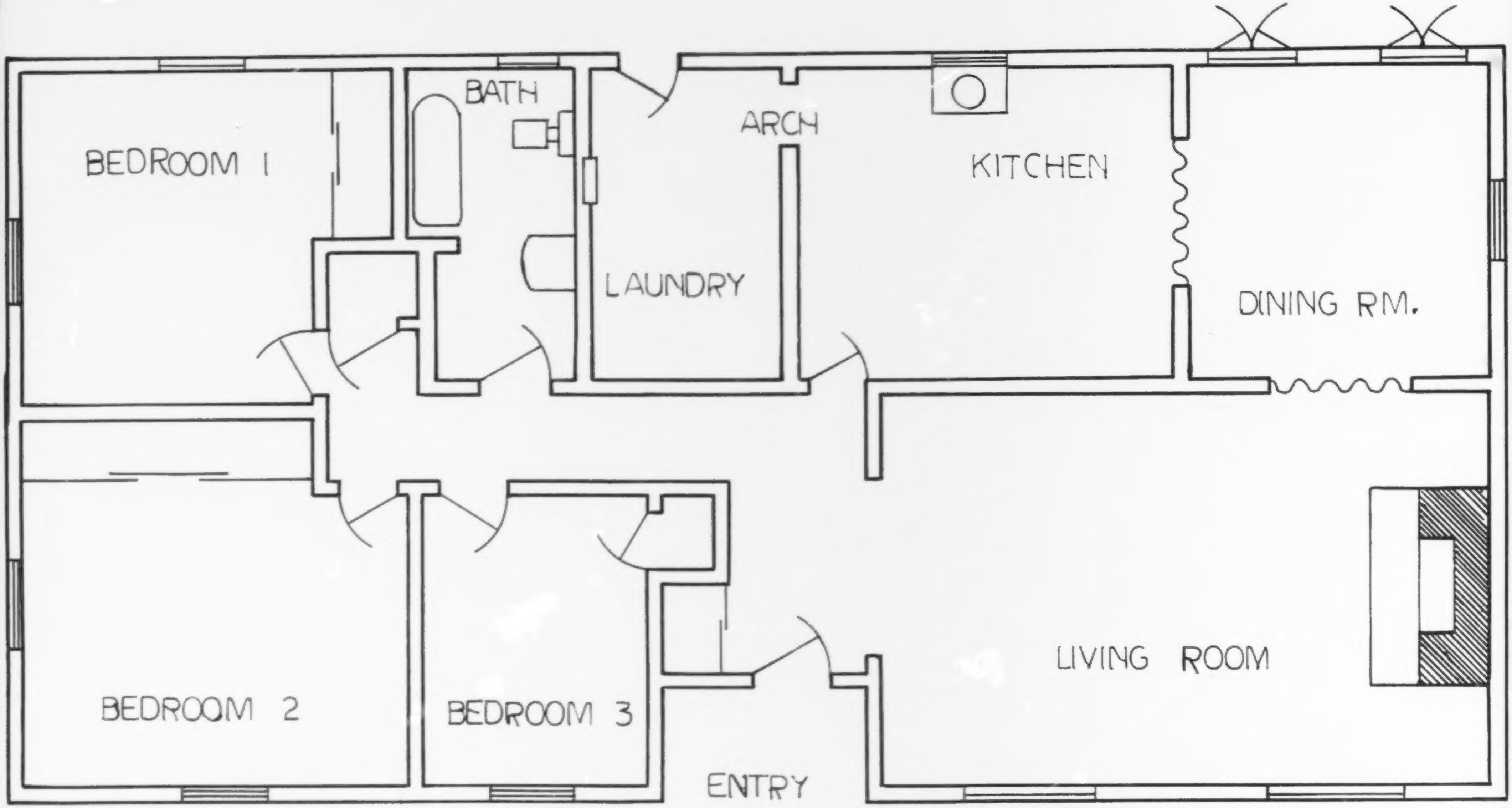
Blueprint Reading and Load Calculations
Unit 1

Assignment Sheet 5—Locate Required Receptacle and Lighting Outlets on a House Plan

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Symbol locations for receptacle and lighting outlets meet minimum *NEC* requirements	_____
Symbols drawn correctly	_____
Symbols used correctly	_____

Directions: Using the information provided in this unit and the *NEC* requirements, draw in the electrical symbols for the receptacle and lighting outlets to meet minimum requirements on the accompanying house plan.


BATH
ARCH
KITCHEN
BEDROOM 1
LAUNDRY
DINING RM.
LIVING ROOM
BEDROOM 2
BEDROOM 3
ENTRY

Electrical Floor Plan

Rough-In
Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to install receptacle, switch, and lighting outlets for a residential dwelling. The student should demonstrate these competencies by completing the assignment sheet and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to rough-in with their correct definitions.
2. List five locations where at least one receptacle outlet is required.
3. Select true statements concerning planning techniques when placing boxes on plans.
4. Complete statements concerning accepted heights for boxes in various locations.
5. Select true statements concerning the procedure for installing boxes in exterior walls to be brick veneered.
6. Distinguish between box extensions for noncombustible and combustible wall surfaces.
7. List two common methods of finding room centers.
8. Select true statements concerning required outlets.
9. List rules for electrical installations.
10. Locate receptacle, switch, and lighting outlets along a floor line and the ceiling on a blueprint. (Assignment Sheet 1)
11. Locate receptacle outlets along kitchen cabinets. (Assignment Sheet 2)
12. Install a device box when given cabinet height and wall covering. (Job Sheet 1)
13. Install a lighting outlet box when given ceiling covering thickness. (Job Sheet 2)

Objective Sheet

14. Wire a switch controlled split-wired receptacle. (Job Sheet 3)

15. Wire a receptacle fed from a lighting outlet through a single pole switch. (Job Sheet 4)

16. Wire a receptacle fed from a lighting outlet through a three-way switch. (Job Sheet 5)

17. Wire a four-way switching situation with the supply entering the lighting outlet box. (Job Sheet 6)

18. Mount a fan box according to manufacturer's recommendations. (Job Sheet 7)

19. Mount a fan box and switch in an existing dwelling according to manufacturer's recommendations. (Job Sheet 8)

Rough-In
Unit 2

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Placement of Electrical Outlets in the Kitchen (Objective 3)
   TM 2—Box Locations (Outside Entrance and Exit) (Objective 3)
   TM 3—Examples of Kitchen Dimensions (For Placement of Boxes) (Objective 4)
   TM 4—Flush Box Installation in Brick Veneer (Objective 5)
   TM 5—Installing Boxes (Flush Mount) (Objective 6)
   TM 6—Locating Center Points for Ceiling Outlet Boxes (Objective 7)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment sheets. Review criteria for evaluation of these activities.

12. Discuss and demonstrate the procedures outlined in the job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

13. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

14. Make copies of the written test. Add or modify test items as needed.

15. Give written test.

16. Record assignment sheet and job sheet ratings, and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

17. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Have students visit a residential construction site where electrical rough-in is exposed. Provide students with a list of questions for them to answer concerning what they observed at the site. Then have students discuss observations in class. Skill areas: **writing, problem solving, listening, and oral communication**.

2. Invite a local or state inspector to class to talk about area building codes pertaining to the wiring of new dwellings. Have students review local code requirements and prepare questions they would like to have answered by the inspector. Provide inspector and students with a copy of the questions so that the inspector will be prepared to answer the questions and the students will be able to record answers for future use. Skill areas: **reading, writing, oral communication, and listening**.

3. Reinforce safety precautions concerning electrical installations.

4. Make extra project assignments to build student's proficiency.

5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.

Suggested Activities

Resources Used in Developing This Unit

1. *1993 National Electrical Code®*. Quincy, MA: National Fire Protection Association, 1992.

   Note: Copies of the 1993 *NEC* may be obtained from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269 or the International Association of Electrical Inspectors, 901 Waterfall Way, Suite 602, Richardson, TX 75080-7702.

2. Taylor, Mark. *Residential Wiring*. Revised. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

Suggested Supplemental Resources

Publications

1. Holzman, Harvey N. *Modern Residential Wiring*. South Holland, IL: Goodheart-Willcox Company, Inc., 1986.

2. Mullin, Ray C. *Electrical Wiring: Residential*, 11th ed. Albany, NY: Delmar Publishers, Inc., 1993.

3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers Inc., 1993.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student edition. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Suggested Activities

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Rough-In
Unit 2

Answers to Assignment Sheets

Assignment Sheet 1 — Evaluated according to the criteria given on the assignment sheet and to the minimum requirements as stated in the 1993 *NEC.*

Assignment Sheet 2 — Evaluated according to the criteria given on the assignment sheet and to the minimum requirements as stated in the 1993 *NEC.*

Rough-In
Unit 2

Answers to Written Test

1. a. 2
   b. 6
   c. 1
   d. 7
   e. 3
   f. 5
   g. 4

2. a. Bathroom — Adjacent to sink
   b. Laundry — Within six feet of appliance to be served
   c. Outside
   d. Basement
   e. Attached garage

3. a, d

4. a. 45″
   b. 40″
   c. 12″
   d. 50″

5. b, c, d

6. b

7. a. Corner to corner chalkline and plumb bob transfer
   b. Measuring half wall lengths, out at right angles from the walls

8. b, d, f

9. Any four of the following:

   a. Always be safety conscious.
   b. Do work you will be proud of.
   c. Be sure all connections are secure and well insulated.
   d. Always be sure that overcurrent protection is matched to your conductor rating.
   e. Preform conductors before installing devices.
   f. Use appropriate tools.
   g. Always meet or exceed *NEC*, state, and local code minimum installation requirements.

Rough-In
Unit 2

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

______a. Midpoint on a boxes vertical dimension

______b. Point in a room that is equal distance from parallel walls

______c. That portion of a wall behind the kitchen cabinet, starting at the countertop and ending at the bottom of the wall hung cabinets

______d. Final tile in a ceramic backsplash when the tile is terminated at some point up the wall

______e. Distance that the box extends past the stud

______f. Suitable for people to occupy or live in

______g. Even with the surface

1. Backsplash
2. Box center
3. Box set out
4. Flush
5. Habitable
6. Room center
7. Tile cap

2. List five locations where at least one receptacle outlet is required.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

Written Test

3. Select true statements concerning planning techniques when placing boxes on plans by placing an "X" in the blanks preceding the true statements.

   ______a. Keep spacing even where possible.

   ______b. Put boxes in uneven groups if possible.

   ______c. Check door swing direction so switches are behind doors.

   ______d. Place outside lighting outlets low enough for any fixture.

4. Complete the following accepted heights for boxes in various locations by circling the numbers which best complete each statement.

   a. Above kitchen counter top — (**40″**, **45″**) to box center

   b. Above bathroom cabinets — (**44″**, **40″**) to box center

   c. Receptacles along floor line — (**12″**, **10″**) to box centers

   d. Wall switches — (**46″**, **50″**) to box centers

5. Select true statements concerning the procedure for installing boxes in exterior walls to be brick veneered by placing an "X" in the blanks preceding the correct statements.

   ______a. Punch a large hole in wall sheeting.

   ______b. Push cable through newly formed hole.

   ______c. Put the cable through the back knockout of your box and secure with a cable clamp.

   ______d. Put screws in the device securing holes.

6. Distinguish between box extensions for noncombustible and combustible wall surfaces by placing an "X" next to the location for combustible materials.

   ______a. Not more than ¼″ recess from surface

   ______b. Flush with or projecting from surface.

7. List two common methods of finding room centers.

   a. ____

   b. ____

Written Test

8. Select true statements concerning required outlets by placing an "X" in the blanks preceding the true statements.

______a. In every kitchen, family room, dining room, living room, or similar rooms of dwelling units, receptacle outlets shall be installed so that no point along the floor line in any wall space is more than 8 feet measured horizontally, from an outlet in that space, including any wall space 2 feet or more in width and the space occupied by sliding panels in exterior doors. The wall space afforded by fixed room dividers such as free standing bar type counters, shall be included in the measurement.

______b. In kitchen and dining areas of dwelling units, a receptacle outlet shall be installed at each counter space wider than 12 inches.

______c. At least one receptacle outlet shall be installed in a bathroom adjacent to the commode location.

______d. At least one receptacle outlet shall be installed outdoors.

______e. At least two receptacle outlets shall be installed in laundry areas.

______f. At least one wall switch controlling a lighting outlet is required in every habitable room including the hallway, bathroom, stairway, attached garage, outdoor entrance, and in attics, under floor space, utility rooms, and basements if used for storage or if containing equipment requiring service.

9. List four rules for electrical installations.

a. ____

____

b. ____

____

c. ____

____

d. ____

____

*Permission to duplicate this test is granted.

Rough-In
Unit 2

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Locate Receptacle, Switch, and Lighting Outlets Along a Floor Line and the Ceiling on a Blueprint Rating ______

Comments: ____

____

Assignment Sheet 2—Locate Receptacle Outlets Along Kitchen Cabinets Rating ______

Comments: ____

____

Job Sheet 1—Install a Device Box When Given Cabinet Height and Wall Covering Rating ______

Comments: ____

____

Job Sheet 2—Install a Lighting Outlet Box When Given Ceiling Covering Thickness Rating ______

Comments: ____

____

Job Sheet 3—Wire a Switch Controlled Split-Wired Receptacle Rating ______

Comments: ____

____

Job Sheet 4—Wire a Receptacle Fed From a Lighting Outlet Through a Single Pole Switch Rating ______

Comments: ____

____

Unit Evaluation Form

Job Sheet 5—Wire a Receptacle Fed From a Lighting Outlet Through a Three-Way Switch Rating ______

Comments: ____

____

Job Sheet 6—Wire a Four-Way Switching Situation With the Supply Entering the Lighting Outlet Box Rating ______

Comments: ____

____

Job Sheet 7—Mount a Fan Box According to Manufacturer's Recommendations Rating ______

Comments: ____

____

Job Sheet 8—Mount a Fan Box and Switch in an Existing Dwelling According to Manufacturer's Recommendations Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

***Permission to duplicate this form is granted.**

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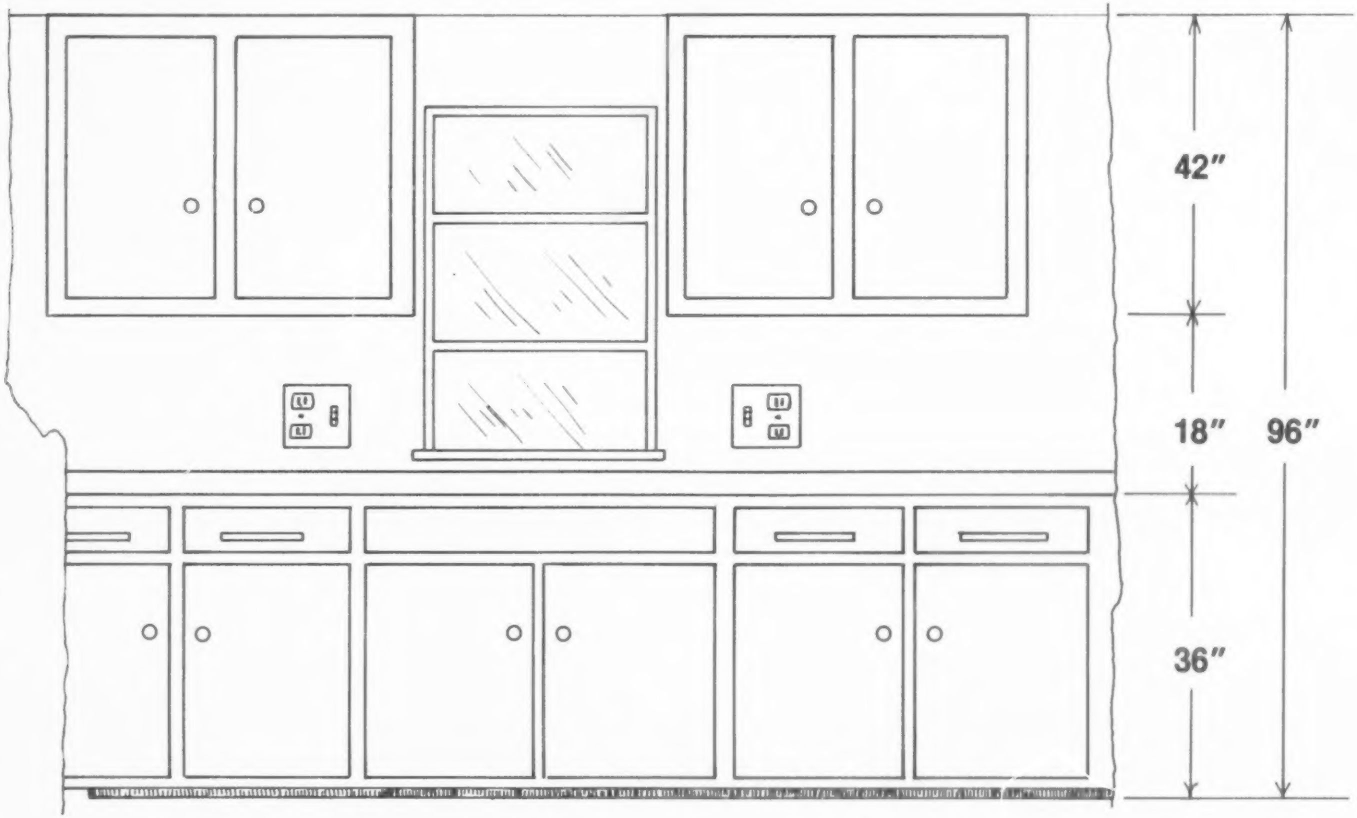
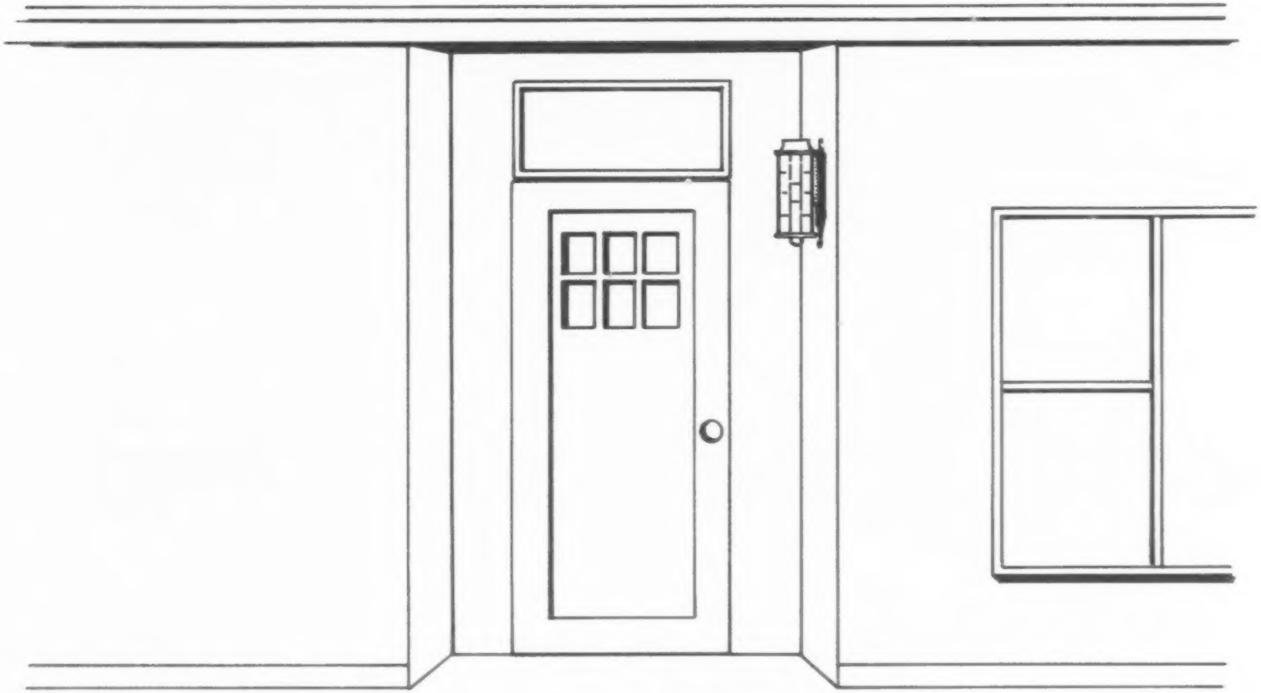
Placement of Electrical Outlets in the Kitchen



Putting Switches and Receptacles in Even Groups
Makes the Job Look Planned

Box Locations (Outside Entrance and Exit)

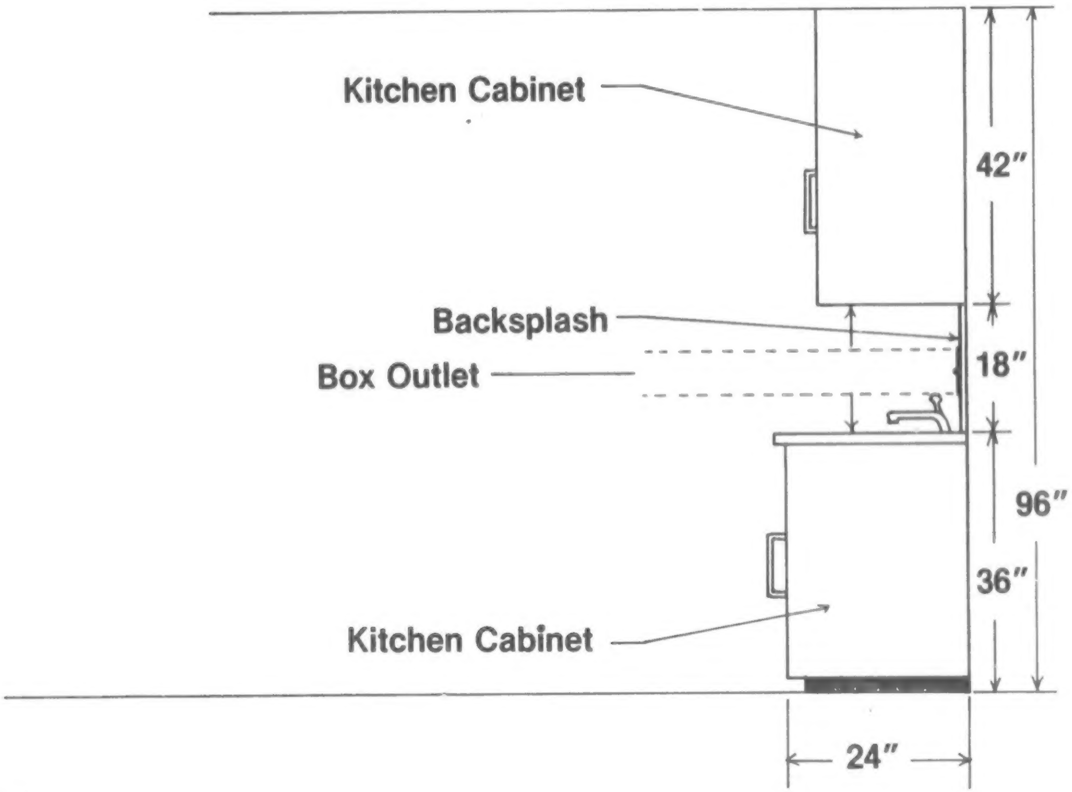


Keeping Boxes at Least Two Feet from the Top Plate
Will Allow Full View of the Larger Fixtures

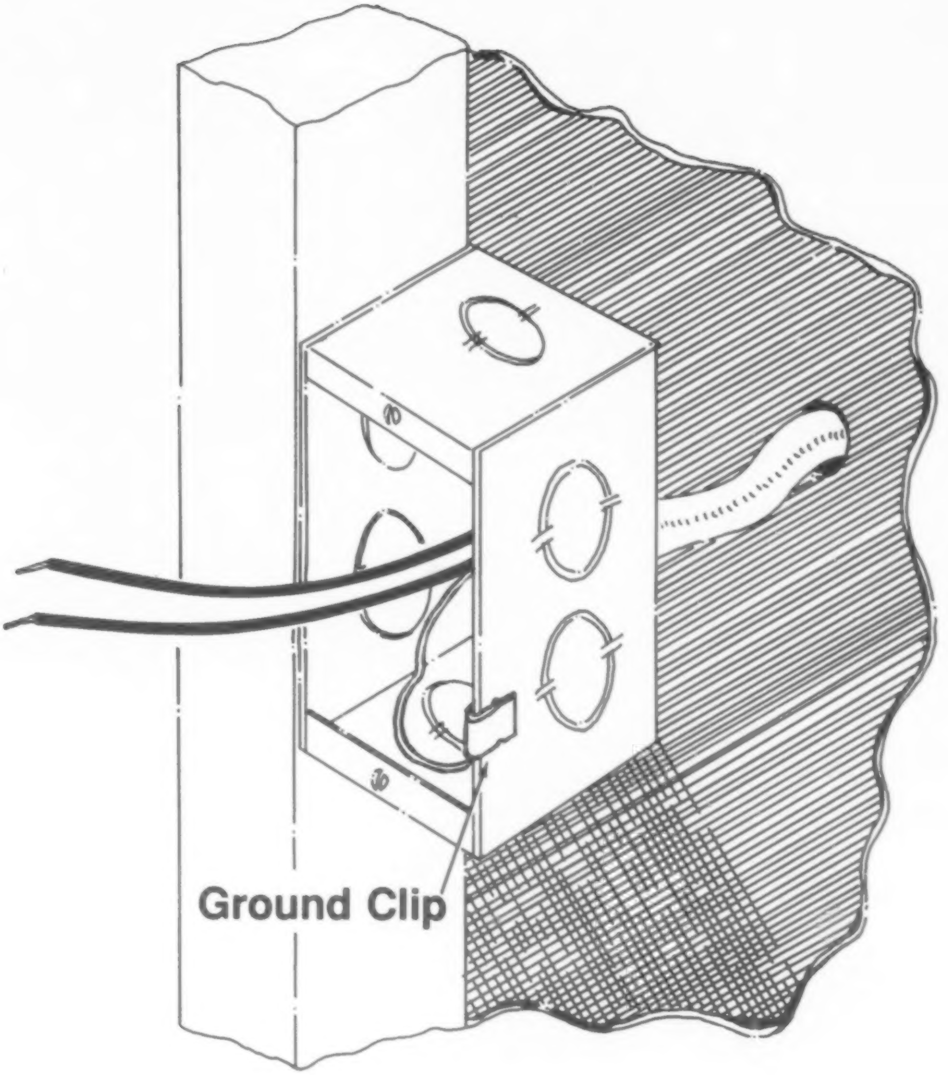
Residential Wiring, Unit 2
Teacher Page 17

TM 2

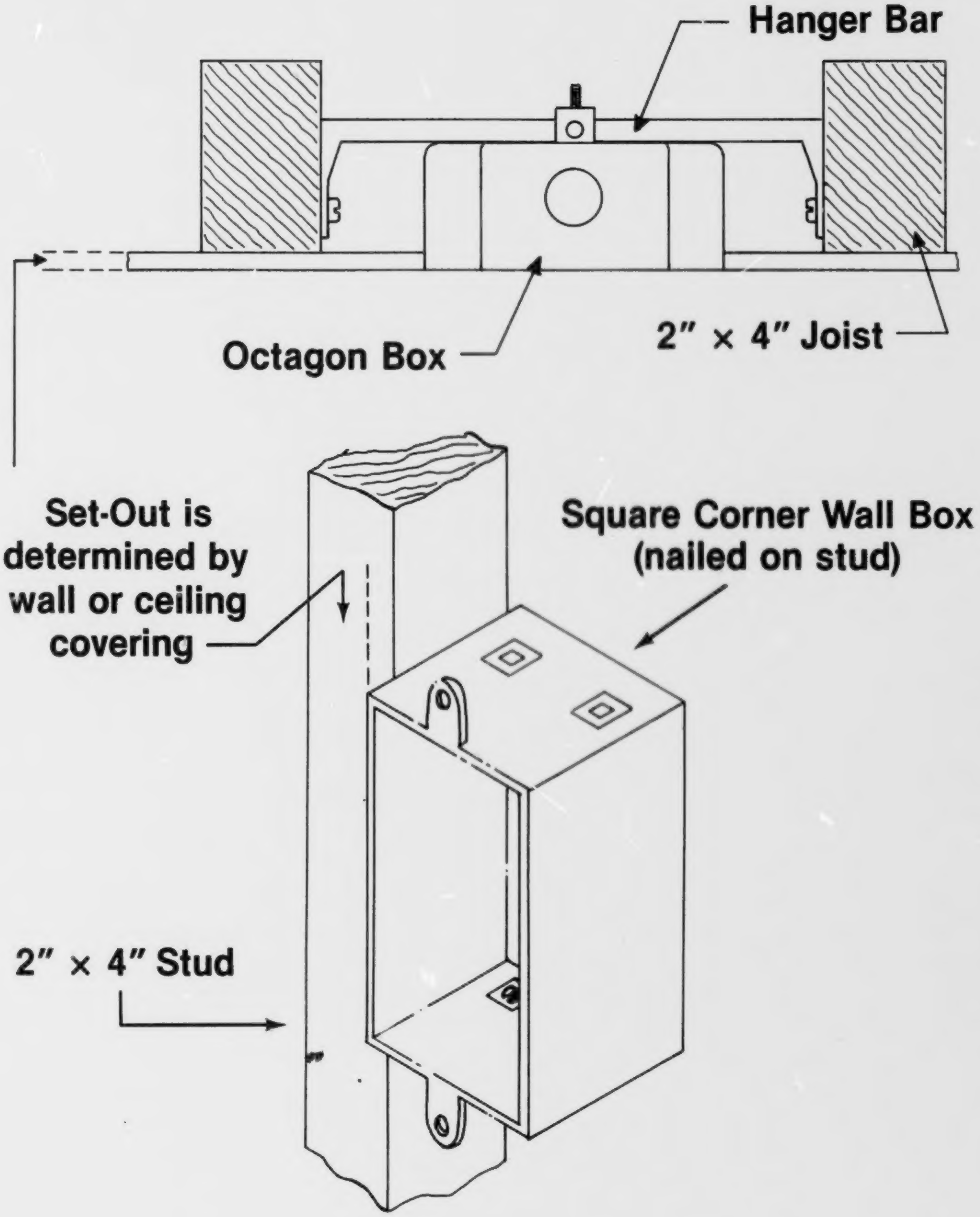
Examples of Kitchen Dimensions (For Placement of Boxes)


Kitchen Cabinet
42"
Backsplash
Box Outlet
18"
96"
36"
Kitchen Cabinet
24"

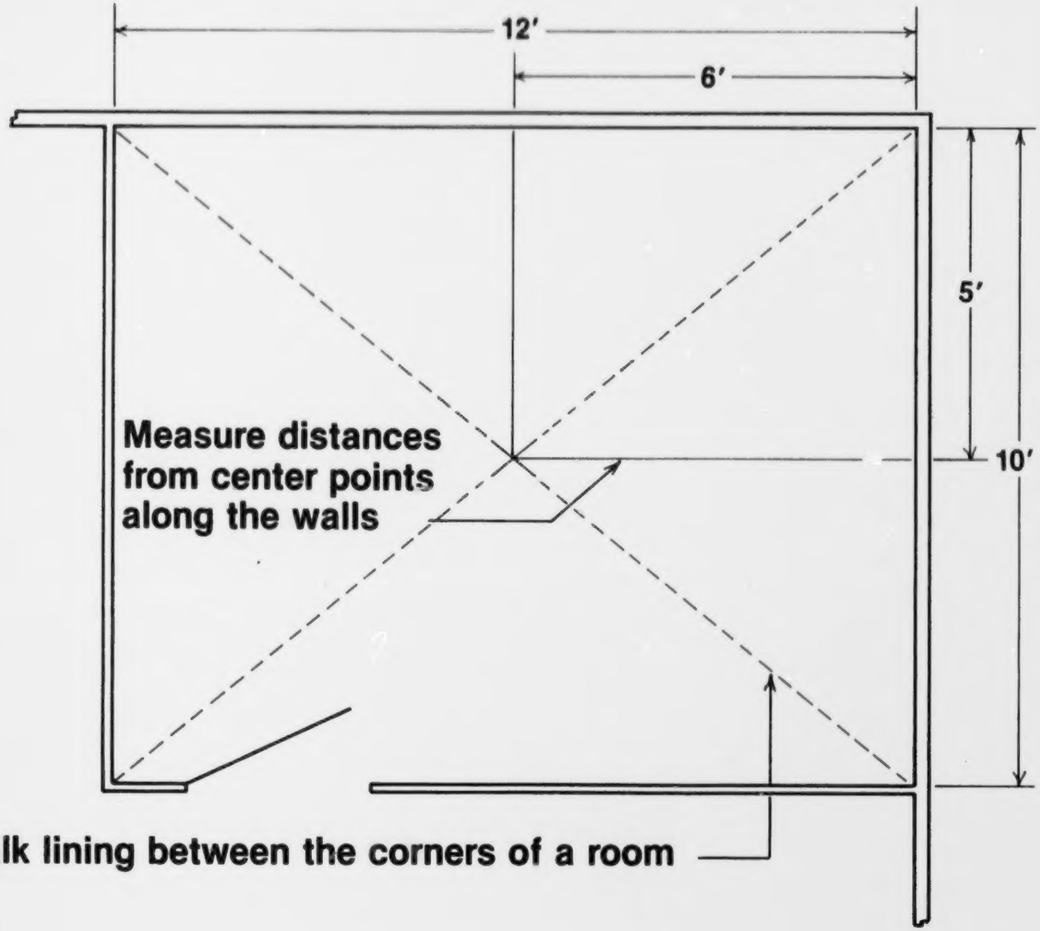
Flush Box Installation in Brick Veneer


Ground Clip

Installing Boxes (Flush Mount)


Hanger Bar
Octagon Box
2″ × 4″ Joist
Set-Out is determined by wall or ceiling covering
Square Corner Wall Box (nailed on stud)
2″ × 4″ Stud

Locating Center Points for Ceiling Outlet Boxes



Measure distances from center points along the walls

Chalk lining between the corners of a room

Rough-In
Unit 2

Information Sheet

1. **Terms and definitions**

   a. **Backsplash** — That portion of a wall behind the kitchen cabinet, starting at the countertop and ending at the bottom of the wall hung cabinets

   b. **Box center** — Midpoint on a boxes vertical dimension

   c. **Box set out** — Distance that the box extends past the stud

   d. **Flush** — Even with the surface

   e. **Habitable** — Suitable for people to occupy or live in

   f. **Room center** — Point in a room that is equal distance from parallel walls

   g. **Tile cap** — Final tile in a ceramic backsplash when the tile is terminated at some point up the wall

2. **Locations where at least one receptacle outlet is required**

   a. Bathroom — Adjacent to sink

   b. Laundry — Within six feet of appliance to be served

   c. Outside (2 minimum)

   d. Basement

   e. Attached garage

3. **Planning techniques when placing boxes on plans**

   a. Keep spacing even where possible

   b. Put boxes in even groups if possible

   c. Check door swing direction so switches are not behind doors

   d. Place outside lighting outlets low enough for any fixture

Information Sheet

4. **Accepted heights for boxes in various locations**

   Note: You should ask the cabinetmaker how tall the cabinets are going to be when you are unfamiliar with the cabinetmaker's work.

   a. Above kitchen counter top — 45″ to box center

      Note: Tops are usually 36″, ½ of 18″ backsplash equals 9″, total height is then 45″ from finished floor.

   b. Above bathroom cabinets — 40″ to box center

      Note: This allows for a 44″ or higher tile cap.

   c. Receptacles along floor line — 12″ to box centers

   d. Wall switches — 50″ to box centers from finished floor

5. **Procedure for installing boxes in exterior walls to be brick veneered**

   Note: Before installing any boxes in exterior brick walls, check your local code.

   a. Punch a small hole in wall sheeting.

   b. Push cable through newly formed hole.

   c. Put the cable through the back knockout of your box and secure with a cable clamp.

      Note: Leave plenty of cable so the mason can move the box to fit the masonry work.

   d. Put screws in the device securing holes.

      Note: This keeps the screw holes from becoming filled with mortar.

Information Sheet

6. **Box extensions for noncombustible and combustible wall surfaces**

   a. Non combustible materials — Not more than ¼" recess from surface

   b. Combustible materials — Flush with or projecting from surface

7. **Common methods of finding room centers**

   a. Corner to corner chalk line and plumb bob transfer

   b. Measuring half wall lengths, out at right angles from the walls

8. **Required outlets**

   a. Receptacle outlets

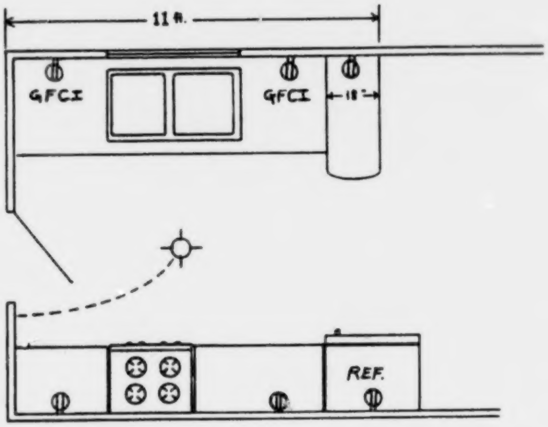
      - General provisions — In every kitchen, family room, dining room, living room, or similar rooms of dwelling units, receptacle outlets shall be installed so that no point along the floor line in any wall space is more than 6 feet measured horizontally, from an outlet in that space, including any wall space 2 feet or more in width and the space occupied by sliding panels in exterior doors. The wall space afforded by fixed room dividers such as free standing bar type counters, shall be included in the measurement.

        Note: A wall space shall be considered a wall unbroken along a floor line by doorways, fireplaces, or similar openings. Each wall space 2 ft. wide or greater shall be treated individually and separately from other wall spaces. A wall space can include two or more walls (around corners) where unbroken at the floor line.

Information Sheet

- Counter tops — In kitchen and dining areas of dwelling units, a receptacle outlet shall be installed at each counter space wider than 12 inches.

  Note: Counters divided by ranges, sinks, or refrigerators shall be considered separate cabinets. Refer to *NEC* Art: 210-52(c).



- Bathrooms — At least one receptacle outlet shall be installed adjacent to the basin location.

  Note: Refer to *NEC* Art: 210-8.

- Outdoors — At least one receptacle outlet shall be installed outdoors.

- Laundry areas — At least one receptacle outlet shall be installed in laundry areas.

  Note: Refer to *NEC* Art: 210-8(a)4.

- Basements and attached garages — At least one receptacle outlet shall be installed in addition to any for laundry equipment.

  Note: Refer to *NEC* Art: 210-8(a)

- Hallways — 10 feet or more

Information Sheet

b. Lighting outlets required — At least one wall switch controlling a lighting outlet in every habitable room including the hallway, bathroom, stairway, attached garage, outdoor entrance, and in attics, under floor space, utility rooms, and basements if used for storage or if containing equipment requiring service.

   Note: In habitable rooms, other than kitchens or bathrooms, one or more receptacles controlled by a wall switch shall be permitted in lieu of lighting outlets.

c. Attic space — At least one receptacle is required if equipment needing service is contained

9. Rules for electrical installations

a. Always be safety conscious.

b. Do work you will be proud of.

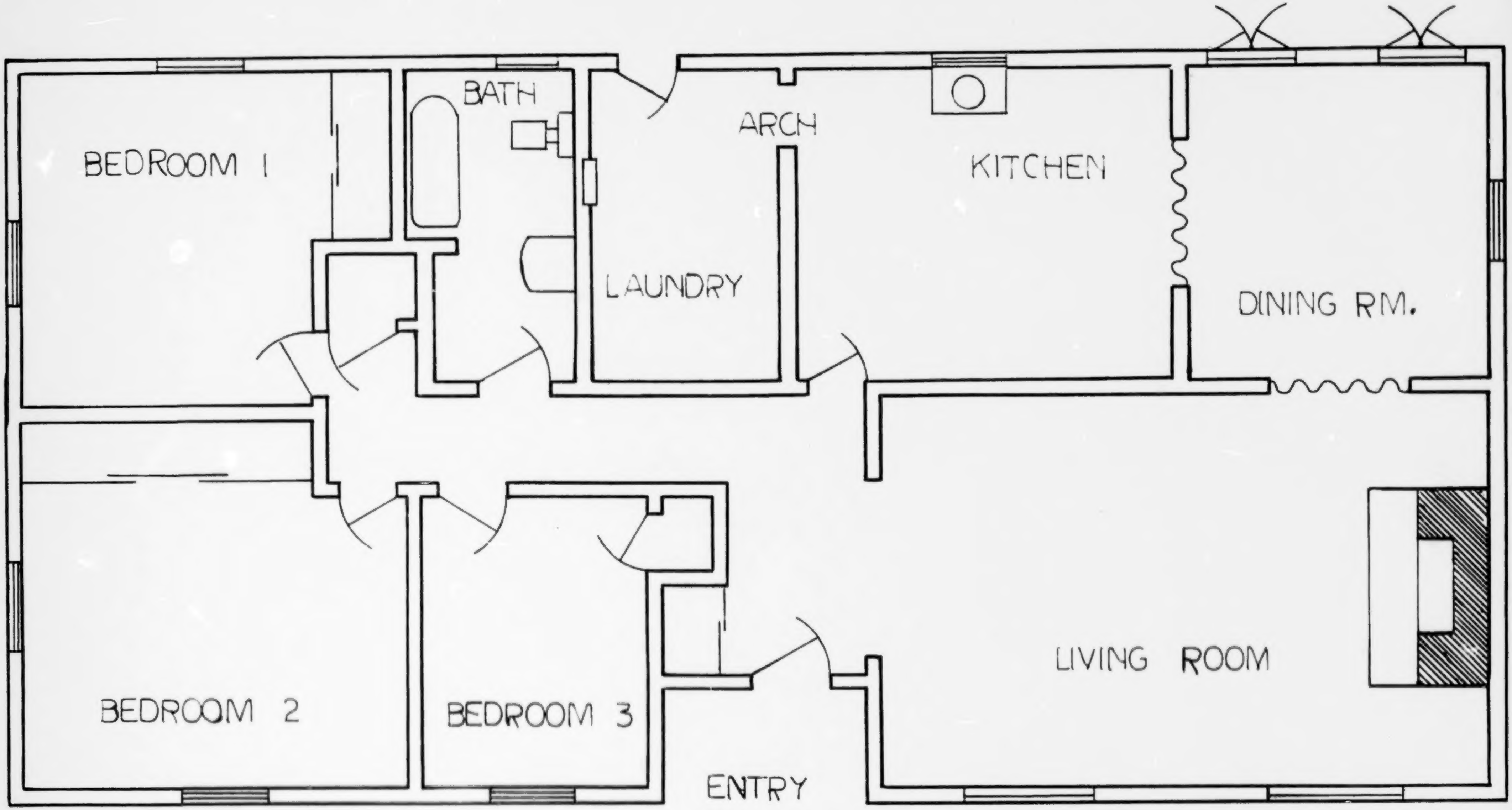
c. Be sure all connections are secure and well insulated.

d. Always be sure that overcurrent protection is matched to your conductor rating.

e. Preform conductors before installing devices in boxes.

f. Use appropriate tools.

g. Always meet or exceed *NEC*, state, and local code minimum installation requirements.


BATH
ARCH
BEDROOM 1
KITCHEN
LAUNDRY
DINING RM.
LIVING ROOM
BEDROOM 2
BEDROOM 3
ENTRY

Electrical Floor Plan

Rough-In
Unit 2

Assignment Sheet 1—Locate Receptacle, Switch, and Lighting Outlets Along a Floor Line and the Ceiling on a Blueprint

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Used appropriate blueprint symbols	______
Located minimum required receptacle switch and lighting outlets	______
Neat, legible work	______

Directions: Using appropriate blueprint symbols, locate the minimum required receptacle switch and lighting outlets along the floor line and in the ceiling on the plan on the following page.

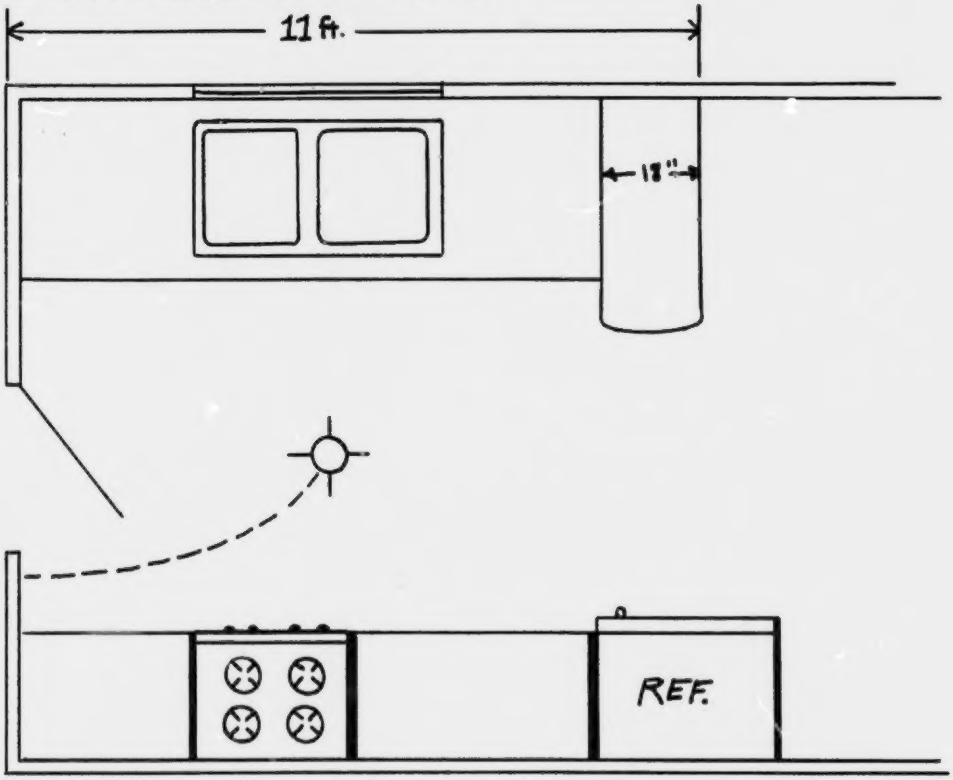
Rough-In
Unit 2

Assignment Sheet 2—Locate Receptacle Outlets Along Kitchen Cabinets

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Used appropriate blueprint symbols	_____
Located minimum required receptacle outlets	_____
Neat, legible work	_____

Directions: Using appropriate blueprint symbols, locate the minimum required receptacle outlets along the cabinet spaces on the print below.



Rough-In
Unit 2

Job Sheet 1—Install a Device Box When Given Cabinet Height and Wall Covering

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Measurements correct	______
Box is set for plasterboard	______
Box is mounted correctly	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

Locate a device box in a backsplash behind a 36″ high counter. The hanging cabinets start 18″ from the counter top. The wall will be covered with ½″ plasterboard.

A. Equipment and materials

Rule
Device box
Hammer
Nails

Note: Some device boxes have nails already attached to the box. If so, no other nails are necessary.

Stud wall

Note: This can be in a new house or a shop mock-up of an unfinished wall with studs exposed.

Safety glasses
Pencil

Job Sheet 1

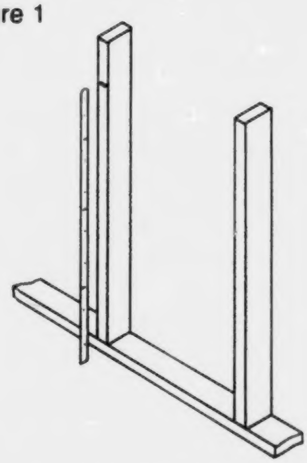
B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

☐ 2. Determine box height and mark the stud for your box center.

Note: In this job, 45″ will be acceptable. That is 36″ cabinet height plus ½ of backsplash which is 9″ (18/2).

Figure 1



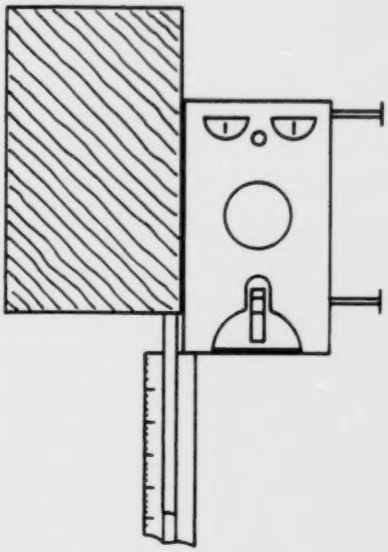
☐ 3. Determine appropriate box set out for wall covering specified.

Note: In this instance for a noncombustible wall, set out is between one quarter and one half inch.

Job Sheet 1

☐ 4. Locate box on center with correct set out.

Figure 2



☐ 5. Drive nails in to secure box.

☐ 6. Check set out again.

☐ 7. Have instructor check your work.

☐ 8. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Rough-In
Unit 2

Job Sheet 2—Install a Lighting Outlet Box When Given Ceiling Covering Thickness

Name ________________________	Attempt Number ________
Date ________________________	Overall Rating ________

Evaluation criteria	**Rating**
Bar hanger mounted correctly	______
Box and hanger mounted properly	______
Box is set for plasterboard	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

Locate a lighting outlet box ceiling to be covered with ½″ plasterboard.

A. Equipment and materials

Rule
4″ octagon box

Note: Any type lighting outlet box can be used for this installation.

Hammer
Bar hanger

Note: Bar hangers come in various lengths. You need to have a hanger that will fit between your studs.

Nails
Stud wall
Safety glasses
Pencil

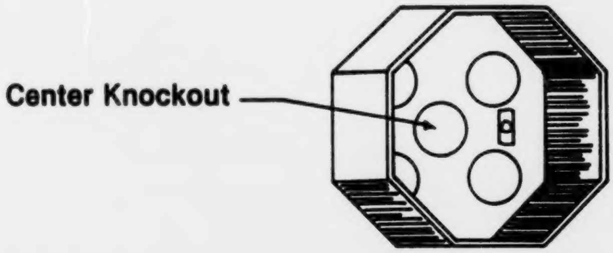
Job Sheet 2

B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

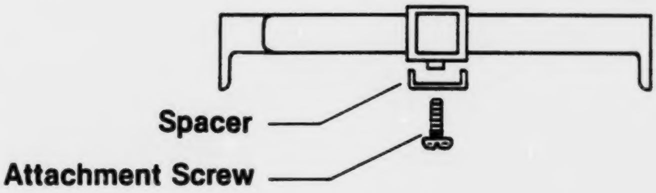
☐ 2. Remove center knock-out from the back of your box.

Figure 1


Center Knockout

☐ 3. Remove attachment screw and spacer from bar hanger.

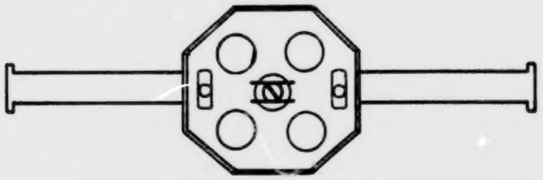
Figure 2


Spacer
Attachment Screw

Job Sheet 2

☐ 4. Mount your box on the bar hanger and secure it loosely with your spacer and attachment screw.

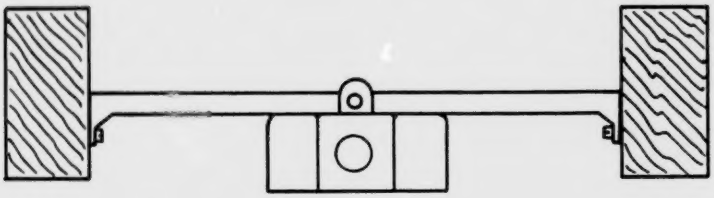
Figure 3



☐ 5. Place bar and box between stud and check set out.

Note: Refer to *NEC* Art: 370-20.

Figure 4



☐ 6. Nail hanger in place.

☐ 7. Check set out again.

☐ 8. Have instructor check your work.

☐ 9. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Rough-In
Unit 2

Job Sheet 3—Wire a Switch Controlled Split-Wired Receptacle

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
Boxes mounted correctly	______
Romex run properly	______
Holes drilled correctly	______
Romex stapled	______
Make-ups correct	______
Grounding correct	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

12-2G or 14-2-G NM cable
12-3G or 14-3-G NM cable
Two device boxes

Note: Be sure boxes have a *NEC* capacity rating to accommodate the conductors you will install.

Staples
Single pole switch
Duplex grounding type receptacle
Stud wall or work board
120v supply

Note: The overcurrent protection on this supply should not exceed the conductors *NEC* ampacity rating.

Job Sheet 3

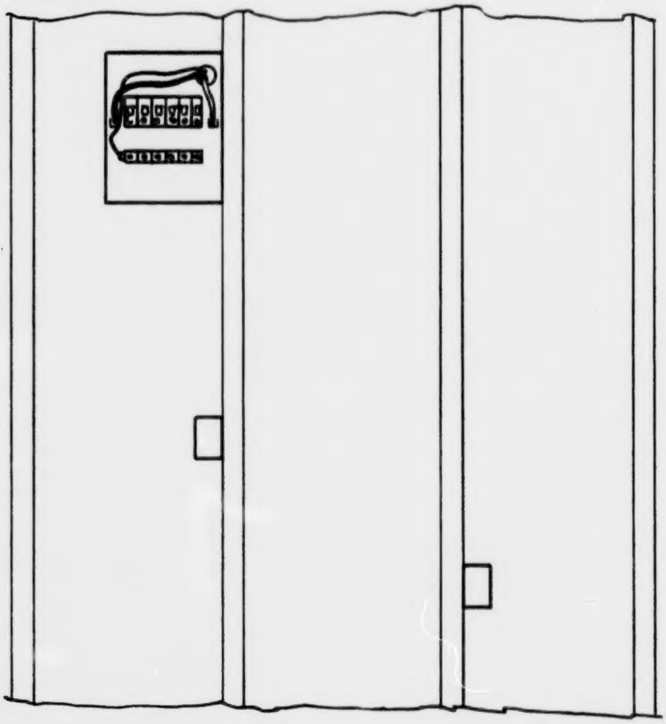
⅜" cable clamp
Wire connectors
Four 16 penny nails or other fasteners as needed to secure the boxes
Electrician's hammer
Plain tip screwdriver
Lineworker's pliers
Needle-nose pliers
Pocket knife
Wire strippers
Tool pouch
Drill motor or brace
½" or larger wood bit
Extension cord
Safety glasses
GFCI

B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

☐ 2. Mount boxes.

Figure 1



Job Sheet 3

☐ 3. Remove a half inch knockout from the panel.

☐ 4. Install cable connector.

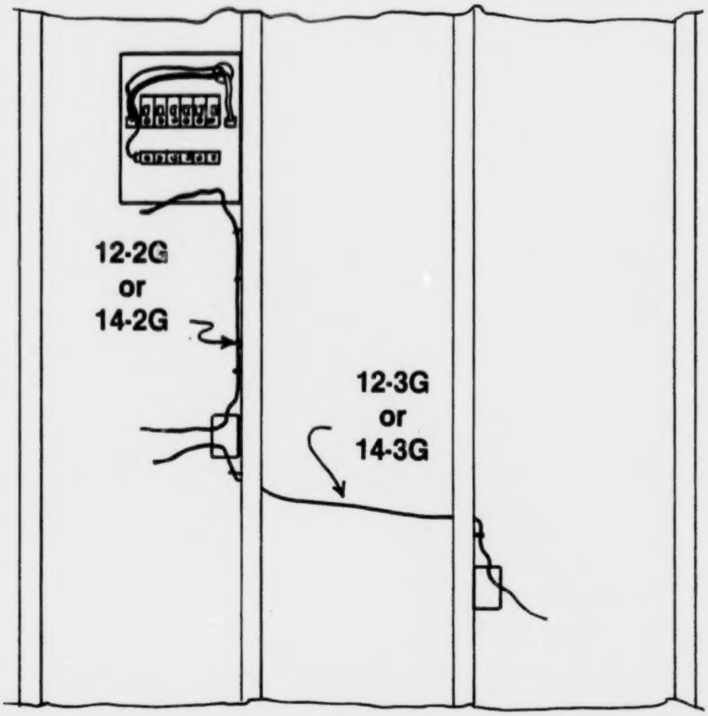
☐ 5. Bore holes for cable.

Note: Holes should be drilled as close to the center (front to back) of a stud as possible. Holes should be drilled at least 6 inches above or below the box depending on which route is the closest.

Caution: Be sure and use a GFCI when drilling.

☐ 6. Run cable between boxes and to panel.

Figure 2



Note: Leave at least 6″ extending past the surface of your device boxes, and enough to reach the top of your panel plus half the width.

Job Sheet 3

☐ 7. Staple cable within 12" of metal boxes, 6" of all nonmetallic boxes.

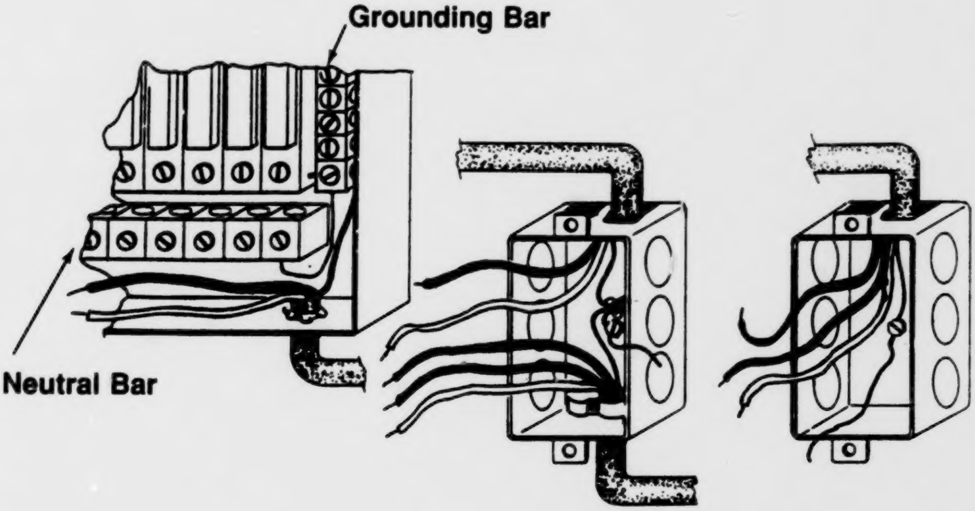
☐ 8. Secure all cable clamps and connectors.

Caution: Tighten them until the cable will not slip in the box; overtightening can cause an electrical short.

☐ 9. Strip cable insulation at device box and panel.

☐ 10. Connect equipment grounding conductors.

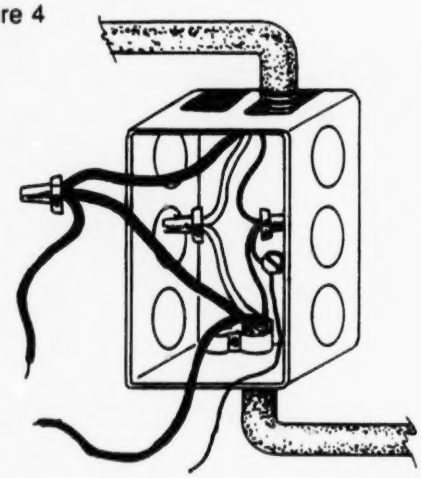
Figure 3



Job Sheet 3

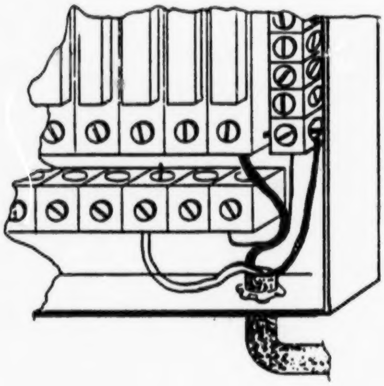
☐ 11. Make up switch box.

Figure 4



☐ 12. Connect grounded and ungrounded conductors.

Figure 5



Connect grounded conductor first

Note: Be sure the breaker is off or the fuse is out before connecting this conductor. Always be safety conscious.

Job Sheet 3

☐ 13. Have your instructor evaluate this project.

☐ 14. Clean work area and put away all equipment and materials.

Evaluator's comments: ______________________________

Rough-In
Unit 2

Job Sheet 4—Wire a Receptacle Fed From a Lighting Outlet Through a Single Pole Switch

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Boxes mounted properly	______
Holes bored correctly	______
Romex run properly	______
Romex stapled	______
Make-up correct	______
Grounded properly	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

12-2G or 14-2-G NM cable
12-3G or 14-3-G NM cable
Two device boxes
Octagon box and bar hanger
Light socket
120 volt bulb
Staples
Single pole switch
Duplex grounding type receptacle
Stud wall or work board
120v supply

Note: The overcurrent protection on this supply should not exceed the conductors *NEC* ampacity rating.

Job Sheet 4

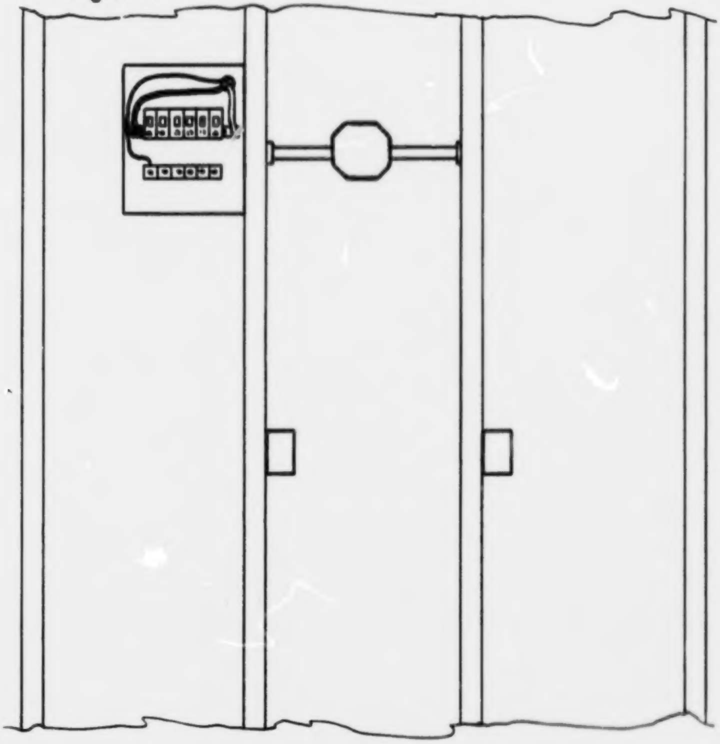
Wire connectors
Four 16 penny nails or other fasteners as needed to secure the boxes
Electrician's hammer
Plain tip screwdriver
Lineworker's pliers
Long nose pliers
Pocket knife
Wire strippers
Tool pouch
Drill motor or brace
½" or larger wood bit
Extension cord
Safety glasses
GFCI

B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

☐ 2. Mount boxes.

Figure 1



Job Sheet 4

☐ 3. Remove a half inch knockout from the panel.

☐ 4. Install cable connector.

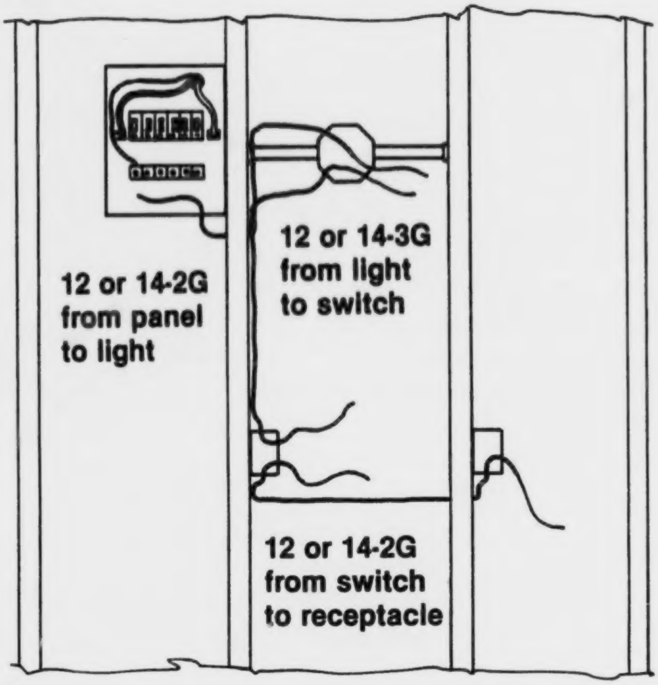
☐ 5. Bore holes for cable.

Note: Holes should be drilled as close to the center (front to back) of a stud as possible. Holes should be drilled at least 6 inches above or below the box depending on which route is the closest.

Caution: Always use a GFCI when drilling.

☐ 6. Run cable between boxes and to panel.

Figure 2


12 or 14-2G from panel to light
12 or 14-3G from light to switch
12 or 14-2G from switch to receptacle

Note: Leave at least 8″ extending past the surface of your device boxes, and enough to reach the top of your panel plus half the width.

Job Sheet 4

☐ 7. Staple cable within 12″ of metal boxes, 6″ of nonmetallic boxes.

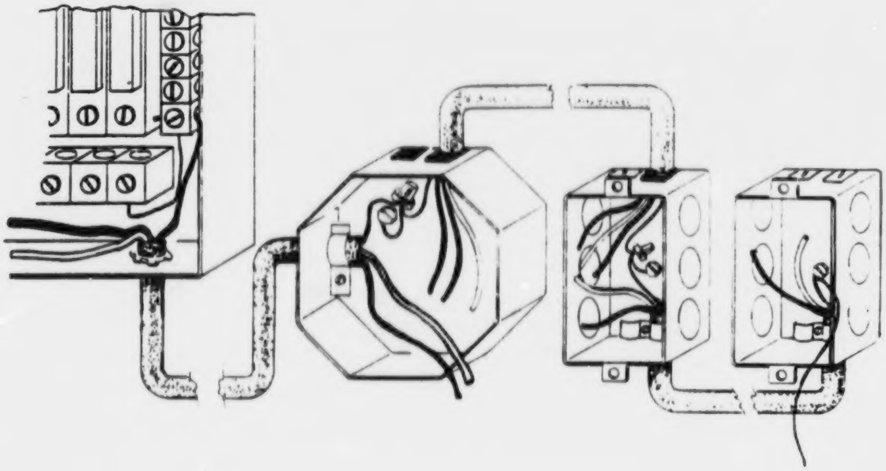
☐ 8. Secure all cable clamps and connectors.

> **Caution: Tighten them until the cable will not slip in the box; overtightening can cause an electrical short.**

☐ 9. Strip cable insulation at device box and panel.

☐ 10. Connect equipment grounding conductors.

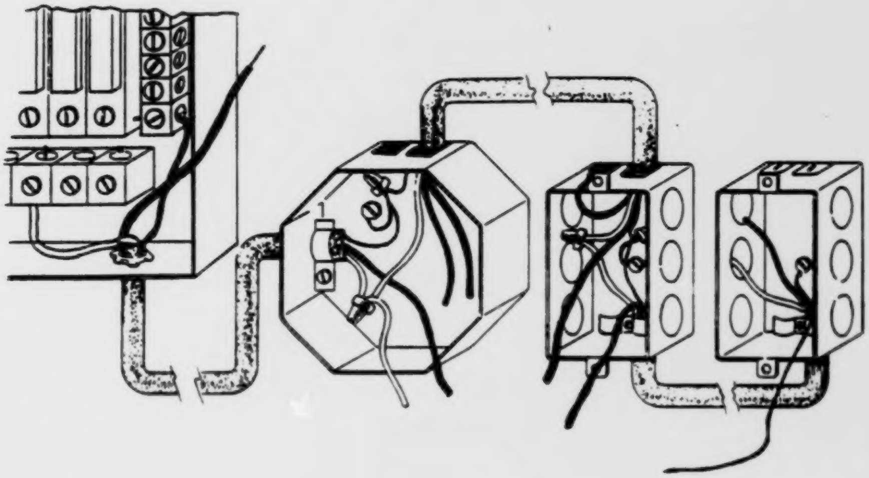
Figure 3



Job Sheet 4

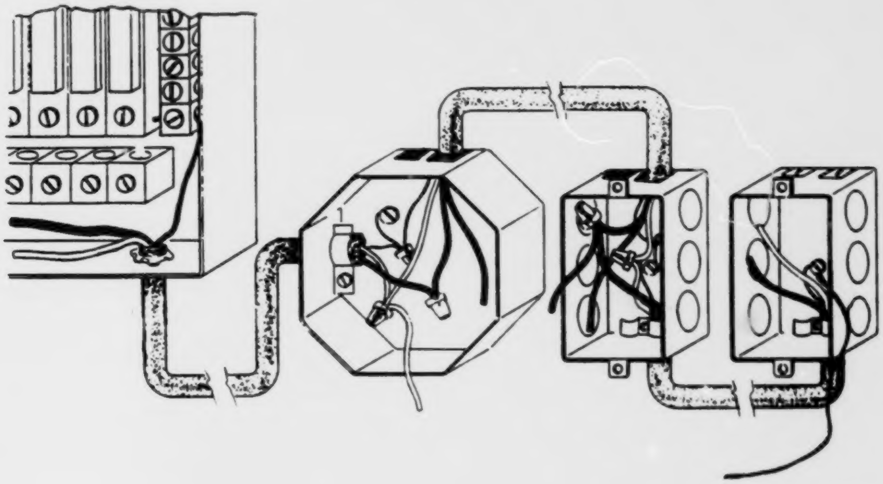
☐ 11. Make up neutral through the system.

Figure 4



☐ 12. Make up switch, return, and feed through conductors.

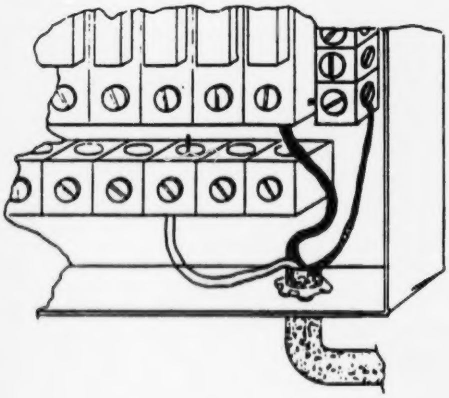
Figure 5



Job Sheet 4

☐ 13. Connect ungrounded conductors.

Figure 6



Note: Be sure the breaker is off or the fuse is out before connecting this conductor. Always be safety conscious.

☐ 14. Have your instructor evaluate this project.

☐ 15. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Rough-In
Unit 2

Job Sheet 5—Wire a Receptacle Fed From a Lighting Outlet Through a Three-Way Switch

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
Boxes mounted correctly	______
Holes drilled properly	______
Romex run correctly	______
Grounding connected	______
Make-up correct	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

12-2G or 14-2-G NM cable
12-3G or 14-3-G NM cable
Three device boxes

Note: One of the device holding boxes will have to be a 4″ square box with a plaster ring.

Octagon box and bar hanger

Note: Be sure boxes have a *NEC* capacity rating to accommodate the conductors to be installed.

Staples
Two 3-way switches
One duplex grounding type receptacle

Job Sheet 5

Light socket
Bar hanger

Note: If a bracket octagon box is used or if this job is installed on a work board, a bar hanger will not be needed.

Stud wall or work board
120v supply

Note: The overcurrent protection on this supply should not exceed the conductors *NEC* ampacity rating.

⅜″ cable clamp
120v incandescent bulb
Wire connectors

Note: Twist on connectors will be used in this manual for illustrations. Wire connectors, pressure connectors, or solder would also be acceptable in the trade.

Two 16 penny nails
Two plasterboard nails
Electrician's hammer
Plain tip screwdriver
Lineworker's pliers
Long nose pliers
Pocket knife
Wire strippers
Tool pouch
Drill motor or brace
½″ or larger wood bit
Extension cord
Safety glasses
GFCI

B. Procedure

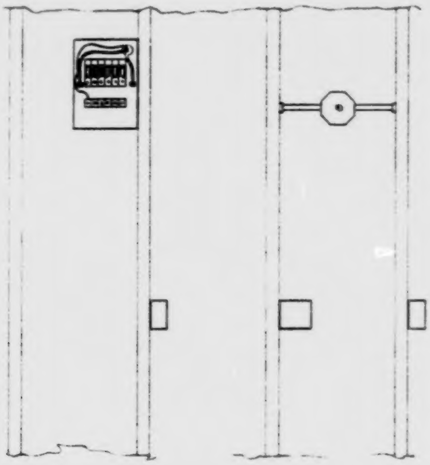
☐ 1. Put on safety glasses and gather equipment and materials.

Job Sheet 5

☐ 2. Mount boxes.

Note: Device boxes and ceiling can be mounted at any height in this project.

Figure 1



☐ 3. Remove a half inch knockout from the panel.

☐ 4. Install cable connector.

☐ 5. Bore holes for cable.

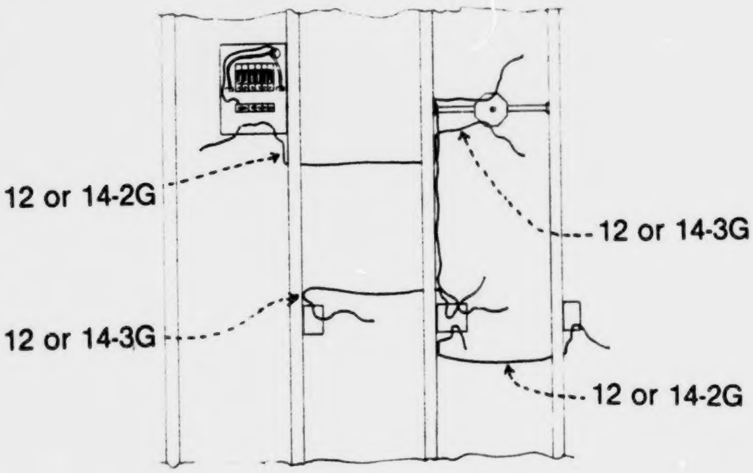
Note: Holes should be drilled as close to the center (front to back) of a stud as possible. Holes should be drilled at least 6 inches above or below the box depending on which route is the closest.

Caution: Be sure and hold the drill securely. A loose grip can cause an accident. Be sure and use a GFCI when drilling.

Job Sheet 5

☐ 6. Run cable.

Figure 2



Note: Leave at least 6″ extending past the surface of your device and lighting outlet boxes, and enough to reach the top of your panel plus half the width.

☐ 7. Staple cable within 12″ of metal boxes, 6″ of nonmetallic boxes.

☐ 8. Secure all cable clamps and connectors.

Caution: Tighten them until the cable will not slip in the box; overtightening can cause an electrical short.

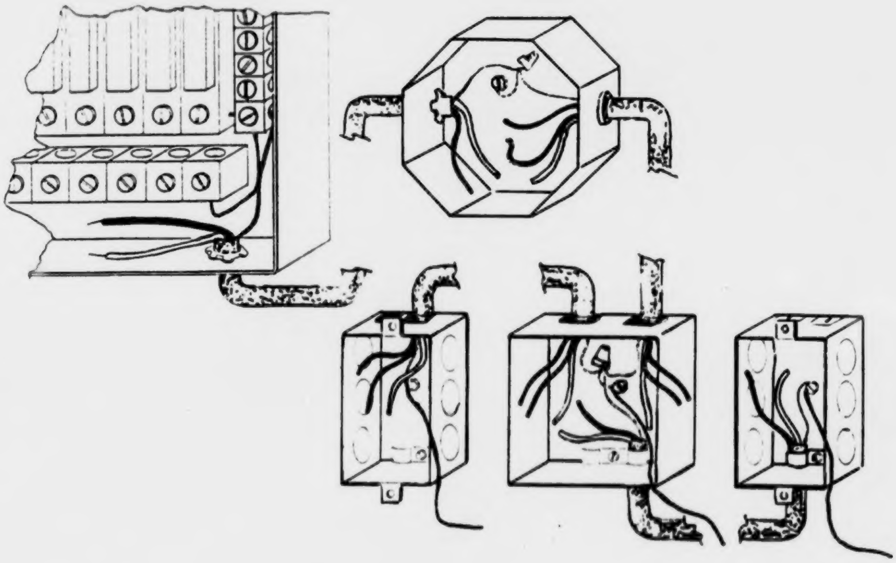
☐ 9. Strip cable insulation.

Caution: Extreme care should always be used in operations involving the knife; a cut hand can cause pain and lost work time.

Job Sheet 5

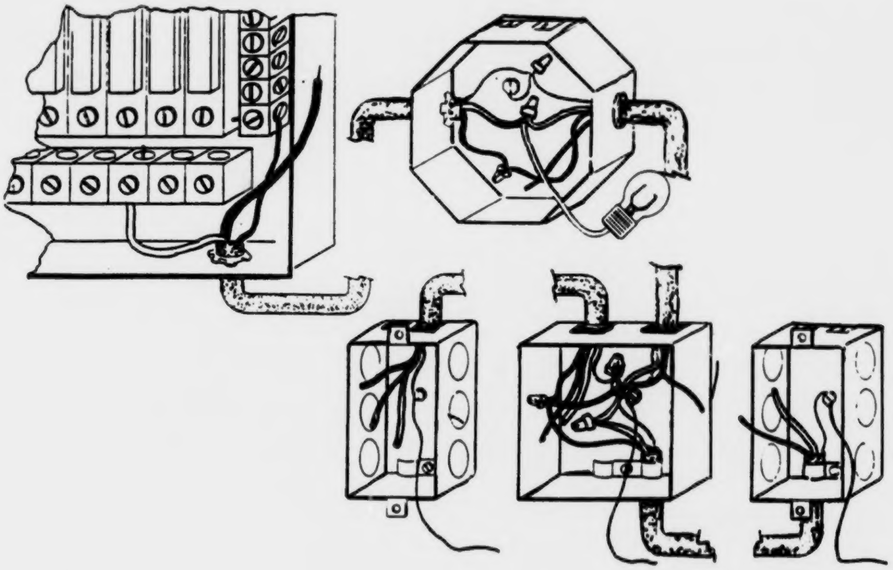
☐ 10. Connect all grounding conductors.

Figure 3



☐ 11. Connect all neutral conductors.

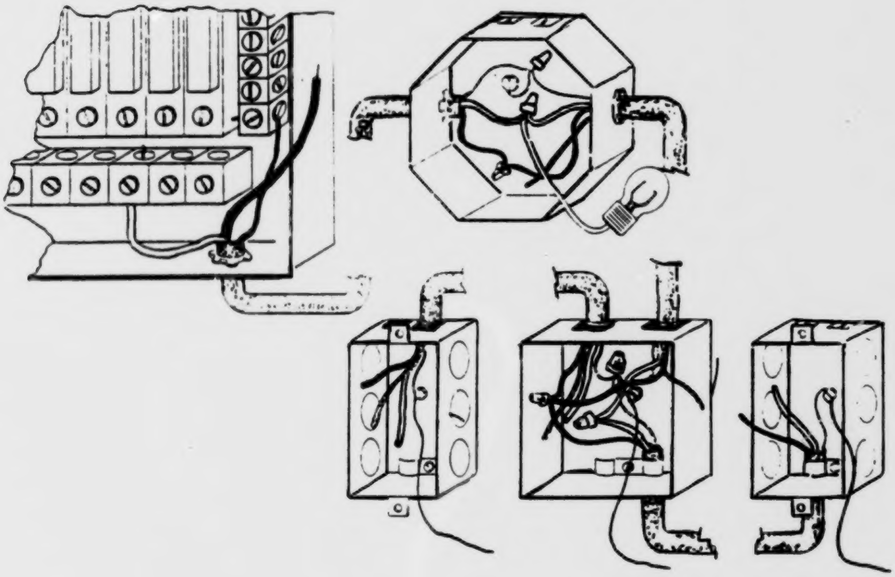
Figure 4



Job Sheet 5

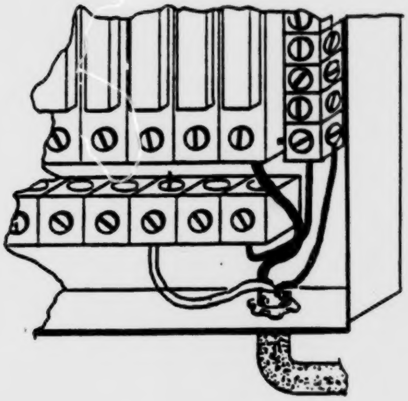
☐ 12. Connect switch leg through the system.

Figure 5



☐ 13. Connect ungrounded conductor to appropriate overcurrent device.

Figure 6



Caution: Be sure the breaker is off or the fuse is out before connecting this conductor. Always be safety conscious.

Job Sheet 5

☐ 14. Have your instructor evaluate this project.

☐ 15. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Rough-In
Unit 2

Job Sheet 6—Wire a Four-Way Switching Situation With the Supply Entering the Lighting Outlet Box

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Devices installed correctly	_____
Light is controlled from either switch	_____
Workmanship	_____
Compliance to *NEC*	_____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

12-2-G or 14-2-G NM cable
12-3-G or 14-3-G NM cable
Three device boxes
Octagon box

Note: Be sure your boxes have a *NEC* capacity rating to accommodate the conductors you will install.

Staples
Two 3-way switches
One 4-way switch
Light socket
Bar hanger

Note: If a bracket octagon box is used or if this job is installed on a work board, a bar hanger will not be needed.

Stud wall or work board
120v supply

Note: The overcurrent protection on this supply should not exceed the conductor's *NEC* ampacity rating.

Job Sheet 6

⅜" cable clamp
120v incandescent bulb
Wire connectors

Note: Twist on connectors will be used in this job sheet for illustrations. Wire connectors, pressure connectors, or solder would also be acceptable in the trade.

Two 16 penny nails
Two plasterboard nails
Electrician's hammer
Plain tip screwdriver
Lineworker's pliers
Long nose pliers
Picket knife
Wire strippers
Tool pouch
Drill motor or brace
½" or larger wood bit
Extension cord
Safety glasses
Portable GFCI

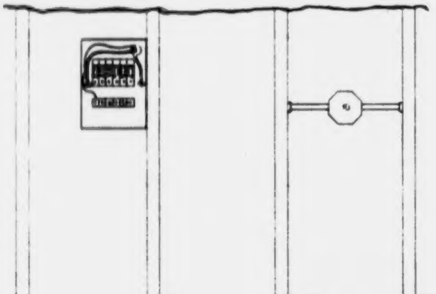
B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

☐ 2. Mount boxes.

Note: Switch box and ceiling outlet can be mounted at any height in this project.

Figure 1



Job Sheet 6

☐ 3. Remove a half-inch knockout from the panel.

☐ 4. Install cable connector.

☐ 5. Plug cord into GFCI.

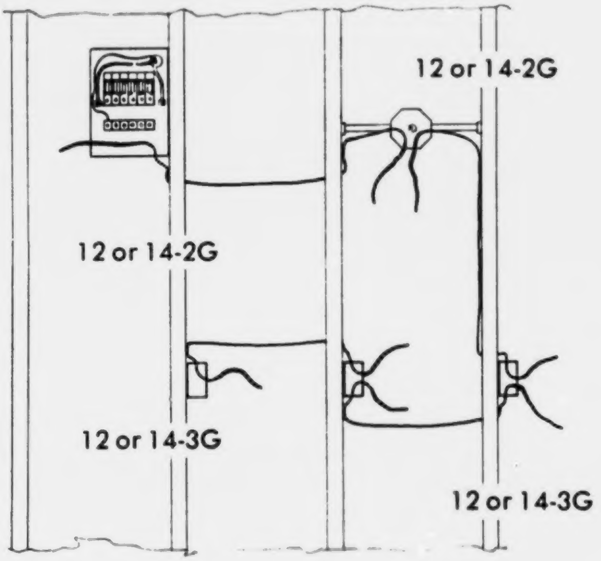
☐ 6. Bore holes for cable; holes should be large enough to safely accommodate the cables.

Note: Holes should be drilled as close to the center (front to back) of a stud as possible. Holes should be drilled at least 6 inches above or below the box depending on which route is the closest.

> **Caution: Be sure and hold the drill securely. A loose grip can cause an accident.**

☐ 7. Run cable.

Figure 2



Note: Leave at least 6" extending past the surface of your device and lighting outlet boxes, and enough to reach the top of your panel plus half the width.

Job Sheet 6

☐ 8. Staple cable within 12″ of metal boxes, 6″ of nonmetallic boxes.

☐ 9. Secure all cable clamps and connectors.

> **Caution: Tighten them until the cable will not slip in the box; overtightening can cause an electrical short.**

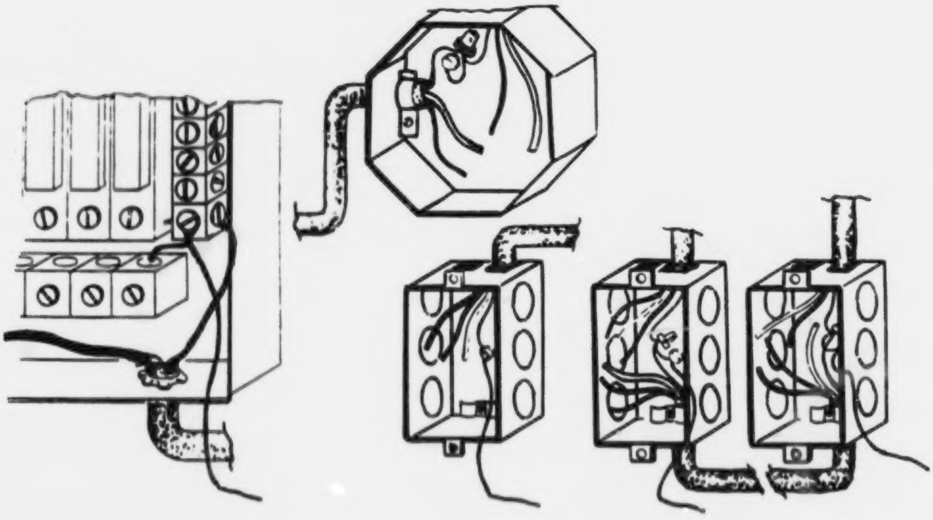
☐ 10. Strip cable insulation.

Note: Trim the cable covering to within ¼″ of its point of entry.

> **Caution: Extreme care should always be used in operations involving a knife; a cut hand can cause pain and lost work time.**

☐ 11. Connect all grounding conductors.

Figure 3

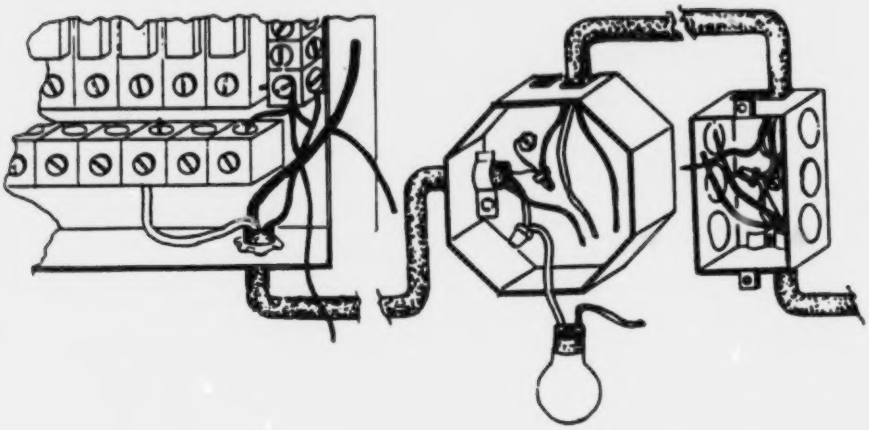


Note: Always leave enough conductor to make removal and reconnection easy. Notice extra bend at panel.

Job Sheet 6

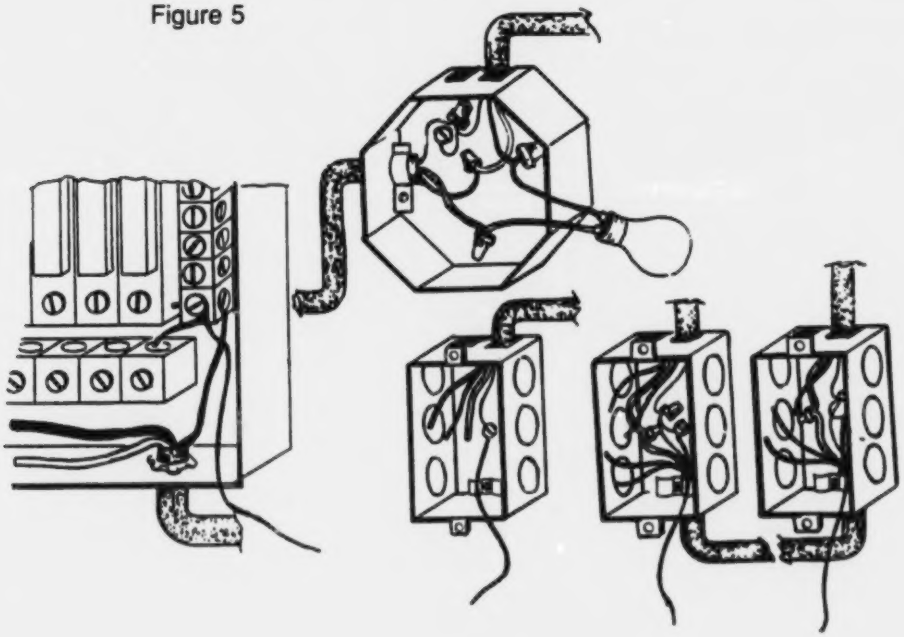
☐ 12. Connect neutral conductors.

Figure 4



☐ 13. Connect switch leg through the system.

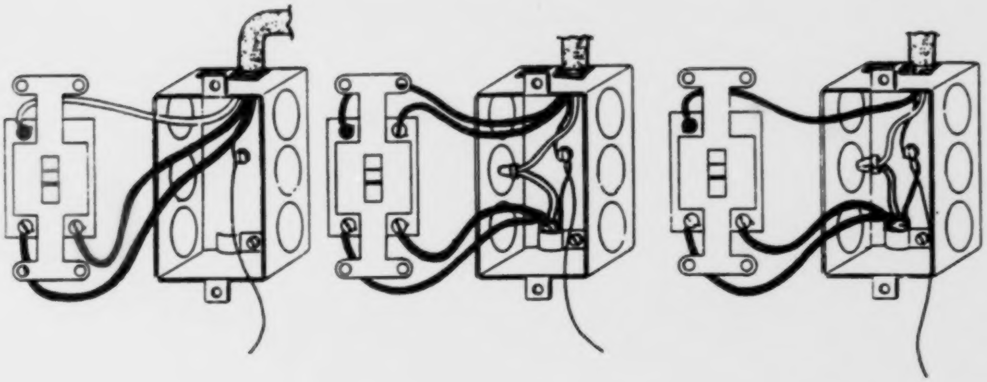
Figure 5



Job Sheet 6

☐ 14. Install switches.

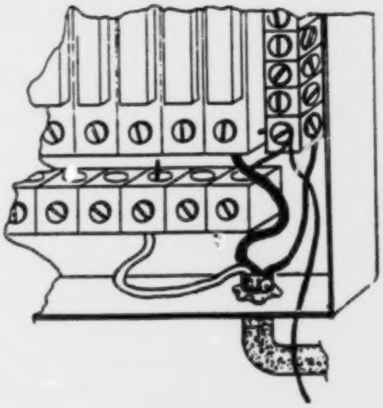
Figure 6



☐ 15. Connect return leg to socket.

☐ 16. Connect ungrounded conductor to appropriate overcurrent device.

Figure 7



Caution: Be sure the breaker is off or the fuse is out before connecting this conductor. Always be safety conscious.

Job Sheet 6

☐ 17. Turn on breaker.

Caution: Stand to the side of the panel when turning on the breaker. A short in the circuit could cause molten metal to fly from the panel.

☐ 18. Change the position of the switches in alternating movements.

Note: Be sure you can turn on or off from either switch as well as on at one and off at the other.

☐ 19. Have your instructor evaluate this project.

☐ 20. Turn off breaker.

☐ 21. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Rough-In
Unit 2

Job Sheet 7—Mount a Fan Box According to Manufacturer's Recommendations

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Measurements correct	______
Box is set for plasterboard	______
Box is mounted correctly	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

Note: Due to the many various styles and brands of fan boxes, it is important that you closely follow the manufacturer's mounting recommendations.

A. Equipment and materials

12-2-G or 14-2-G NMB cable
12-3-G or 14-3-G NMB cable
One 2-gang device box
One fan box with bar hanger
Staples
Two single-pole switches
One ceiling fan with light kit
Rule
Pouch tools
Nails
Safety glasses
Marker or pencil

Job Sheet 7

B. Procedure

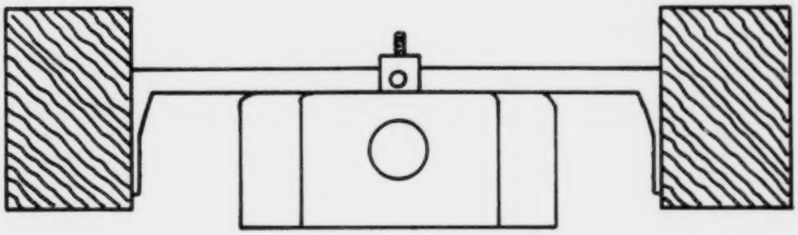
☐ 1. Put on safety glasses and gather equipment and materials.

☐ 2. Find exact location where fan box will be mounted.

☐ 3. Read fan box manufacturer's instructions.

☐ 4. Carefully mount the box with hanger between ceiling joist.

Figure 1



Note: Be sure box set out is in accordance with ½″ plasterboard and *NEC* Art: 370-20. Also, carefully follow the manufacturer's mounting instructions. This is necessary due to the weight of the fan and the likelihood of vibration.

☐ 5. Mount 2-gang device box on stud wall at the proper height above floor.

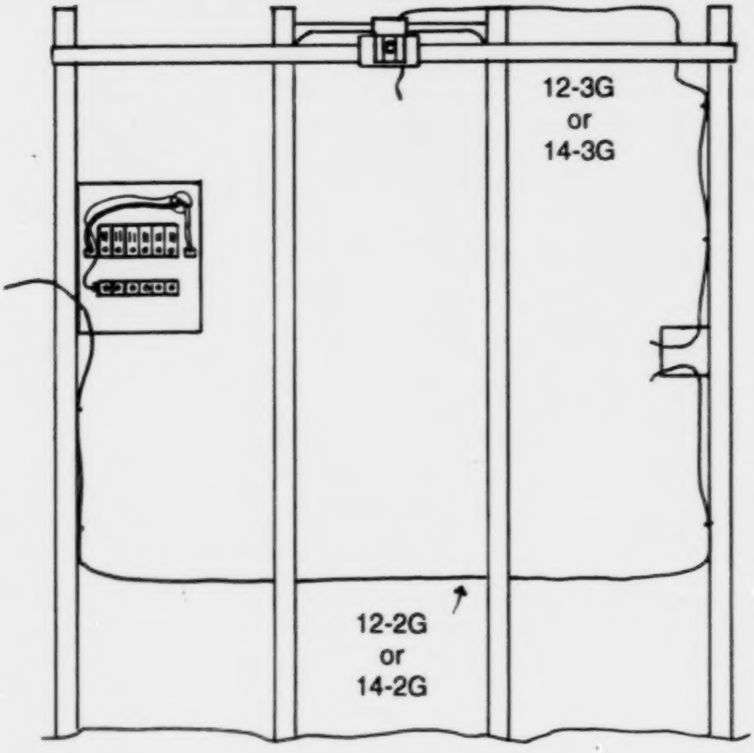
☐ 6. Bore holes for cable routing.

☐ 7. Route a length of 12-2-G NMB or 14-2-G NMB from the power source to the 2-gang device box.

Job Sheet 7

☐ 8. Route a length of 12-3-G NMB or 14-3-G NMB from the power source to the 2-gang device box.

Figure 2



☐ 9. Staple cable within 12″ of metal boxes, 6″ of all nonmetallic boxes.

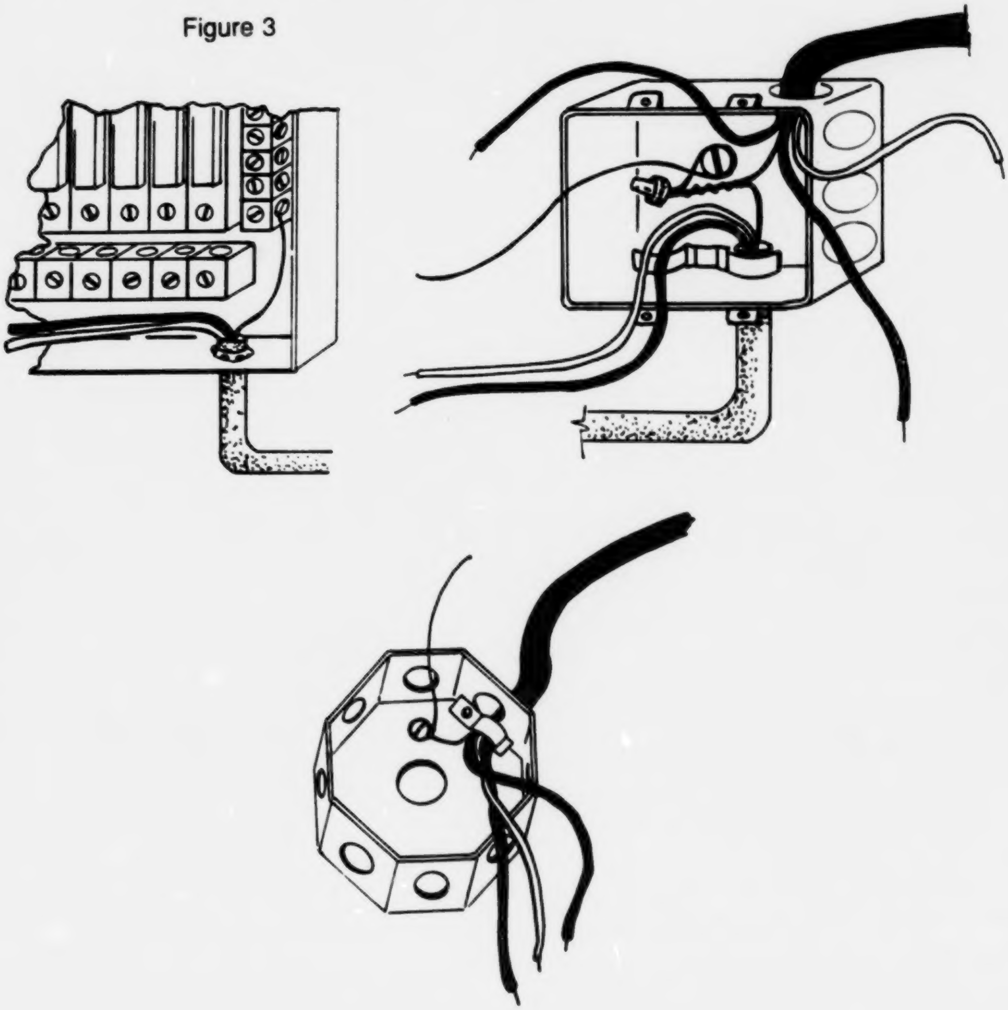
☐ 10. Secure all cable clamps and connectors.

☐ 11. Strip insulation at panel, device box, and fan box.

Job Sheet 7

☐ 12. Connect equipment grounding conductors.

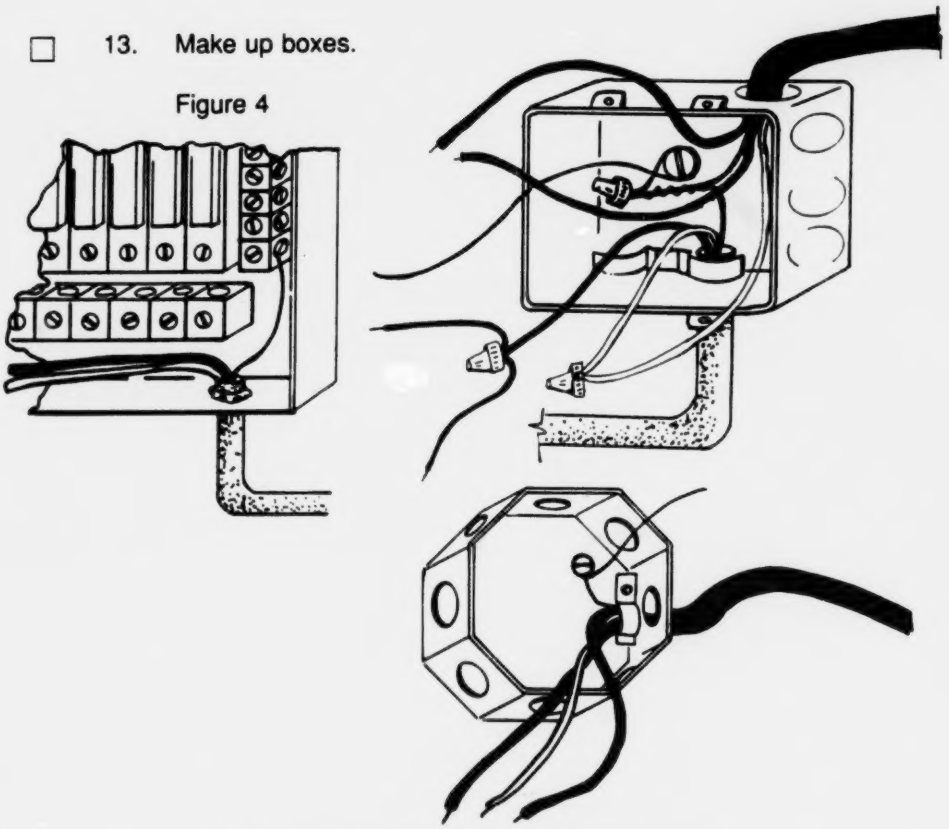
Figure 3



Job Sheet 7

☐ 13. Make up boxes.

Figure 4



☐ 14. Connect grounded and ungrounded conductors.

Note: Be sure breaker is off before connecting this conductor. Always be safety conscious.

☐ 15. Install the switches and the fan.

☐ 16. Have your instructor evaluate this project.

☐ 17. Clean work area and put away all equipment and materials.

Evaluator's comments: ____________________

____

____

Rough-In
Unit 2

Job Sheet 8—Mount a Fan Box and Switch in an Existing Dwelling According to Manufacturer's Recommendations

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Measurements correct	______
Box is set for plasterboard	______
Box is mounted correctly	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

Note: Due to the many various styles and brands of fan boxes, it is important that you closely follow the manufacturer's mounting recommendations.

12-2-G or 14-2-G NMB cable
12-3-G or 14-3-G NMB cable
Fan box with bar hanger
Staples
One ceiling fan with light kit
Rule
Pouch tools
Safety glasses
Marker or pencil

Job Sheet 8

B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

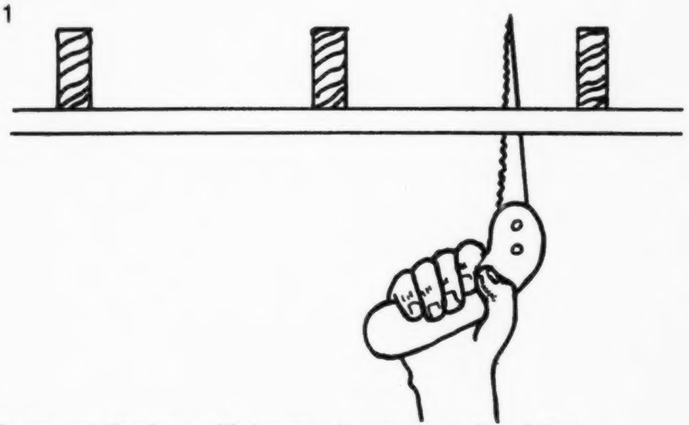
☐ 2. Carefully remove the existing lighting fixture and box.

Note: Be sure the circuit is off and the breaker is tagged and locked out.

☐ 3. Hold the fan box against the ceiling and trace the outline of the box on the ceiling with a pencil.

☐ 4. Enlarge the opening with a keyhole saw if necessary.

Figure 1



☐ 5. Carefully mount the box with hanger between ceiling joists.

Note: Be sure box set is in accordance with the thickness of the plasterboard and *NEC* Art: 370-20. Also, carefully follow the manufacturer's mounting instructions. This may require working from the attic space.

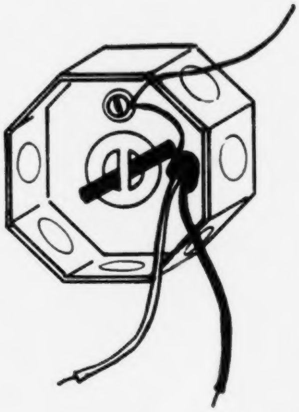
Figure 2

Job Sheet 8

☐ 6. Check that fan box is secure and that you have completely followed the manufacturer's instructions.

☐ 7. Make up the fan box.

Figure 3



☐ 8. Install the fan and light kit.

Note: This installation will require that both the fan and light wire be connected to the same switch leg. The pull switch on the fan will be used to choose fan, light, or both.

☐ 9. Have your instructor evaluate this project.

☐ 10. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Service
Unit 3

Objective Sheet

Unit Objective

After completing this unit, the student should be able to design, size, and install a residential service. The student should demonstrate these competencies by completing the assignment sheet and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to service with their correct definitions.
2. Match required clearances for service drop conductors with their locations.
3. Select true statements concerning service disconnects.
4. List four facts that should be known before the service installation is started.
5. Identify the parts of a service entrance.
6. Select from a list types of grounding electrodes.
7. Select true statements concerning grounding electrode conductor installations and sizes.
8. Select true statements concerning short circuit protection at service equipment.
9. Select true statements concerning surge protection.
10. Calculate service size and minimum number of circuits. (Assignment Sheet 1)
11. Install an overhead raceway with service entrance conductors to a meter base. (Job Sheet 1)
12. Connect meter base assembly to load center or panel. (Job Sheet 2)
13. Install an underground service (lateral) raceway with conductors to a meter base. (Job Sheet 3)

Service
Unit 3

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Parts of a Service Entrance (Objective 5)
   TM 2—Parts of a Service Entrance—Continued (Objective 5)
   TM 3—Parts of a Service Entrance—Continued (Objective 5)
   TM 4—Installing Grounding Rod (Objective 6)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment sheets. Review criteria for evaluation of these activities.

12. Discuss and demonstrate the procedures outlined in the job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

13. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

14. Make copies of the written test. Add or modify test items as needed.

15. Give written test.

16. Record assignment sheet and job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

17. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Have students review Unit 10: Overcurrent Protection in *Basic Wiring*. Skill area: **reading**.

2. Contact a local sales distributor and invite him/her to class to discuss and demonstrate fuses and circuit breaker types. Have students prepare questions in writing beforehand and provide to speaker so that he/she will come prepared to respond to those questions when asked by the students. Provide students with the compiled list of questions so that they may record the answers for future use. Skill areas: **writing, oral communication, and listening**.

3. Invite a local utility representative to class to discuss local requirements for services and meter demonstration. Have students review local code requirements and prepare questions that they would like to have answered by guest speaker. Provide students with list of questions so that they can record the answers for future use. Skill areas: **writing, oral communication, and listening.**

4. Contact your local code enforcement (inspection) department to schedule a class presentation concerning local regulations and requirements for service installation and grounding. This activity may be combined with 3. so that discusson can be interactive among speakers and students. Skill area: **listening**.

5. If possible, plan an on-site visit to a residence under construction to see rough-in of service installation—underground or overhead or both. Have students take notes on what they observe, then discuss their observations in class. Skill areas: **listening, oral communication, and creative thinking**.

6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.

Suggested Activities

Resources Used in Developing This Unit

1. *Buss Fuses — Full Line Condensed Catalog*. St. Louis, MO: Bussman Division, McGraw Edison Company.

   Note: For a copy of this catalog, write to P.O. Box 14460, St. Louis, MO 63178.

2. *D Digest 1987*. Palatine, IL: Square D Company.

3. Earl, John T. *Electrical Wiring Design and Application*. Englewood Cliffs, NJ: Prentice Hall, 1986.

4. Gray, Elliott C., R. Bailey, and E. Melbourne. *Electrical Construction and Maintenance Techniques*. Englewood Cliffs, NJ: Prentice Hall, 1986.

5. Mullin, Ray C. *Electrical Wiring: Residential*, 11th ed. Albany, NY: Delmar Publishers Inc., 1993.

6. *1993 National Electrical Code®*, Quincy, MA: National Fire Protection Association, 1992.

   Note: Copies of the 1993 *NEC* may be obtained from the National Fire Protection Association, Batterymarch Park, Qincy, MA 02269 or the International Association of Electrical Inspectors, 901 Waterfall Way, Suite 602, Richardson, TX 75080-7702.

7. *Pass and Seymour — Wiring Devices Catalog #486*. Syracuse, NY.

   Note: For a copy of this catalog, write to P.O. Box 4822, Syracuse, NY 13221.

8. Richter, Herbert P. and W. Creighton Schwan. *Practical Electrical Wiring*, 15th ed. Englewood Cliffs, NJ: Prentice Hall. 1990.

9. Stallcup, James G. *Designing Electrical Systems Based on the 1990 NEC*. Homewood, IL: American Technical Publishers, Inc., 1989.

10. Taylor, Mark. *Residential Wiring*. Revised. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

Suggested Activities

Suggested Supplemental Resources

Publications

1. Mullin, Ray C. *Electrical Wiring: Residential*, 11th ed. Albany, NY: Delmar Publishers, Inc., 1993.
2. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code®* Albany, NY: Delmar Publishers Inc., 1993.

Films

1. *Electrical Wiring*. Unit IV, Installing Service Equipment. American Association for Vocational Instructional Materials, 120 Engineering Center, Athens, GA 30602.
2. *Electrical House Wiring Explained #803 — #6 Fuse and Circuit Breaker Panels.* Bergwall Productions, Inc., 839 Stewart Ave., Garden City, NY 11530.
3. *Residential Electrical Wiring Explained #804 — 804A.3, Underground Service Entrance.* Bergwall Productions, Inc., 839 Stewart Ave., Garden City, NY 11530.
4. *Electrical Wiring, Unit 1, Number 3, Fuses, Circuit Breakers and GFCI's, Unit I, Number 2, Grounding.* DCA Educational Products, 424 Valley Rd., Warrington, PA 18976.
5. *Wiring A House — Unit 3, Number 1, Overheat Service and Unit 3, Number 2, Installing the Panel.* DCA Educational Products, 424 Valley Rd., Warrington, PA 18976.

Instructions for Evaluating Student Performance

Assignment Sheet—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Suggested Activities

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Service
Unit 3

Answers to Assignment Sheet 1

1. 2,100
2. 6,300
3. 6,300
4. 54.8
5. 3
6. 6,300
7. 10,800
8. 10,800
9. 2,730
10. 5,730
11. 13,730
12. 13,730
13. 57.21
14. 5,730
15. 11,330
16. 11,330
17. 47.21

Service
Unit 3

Answers to Written Test

1.

a.	5	f.	6	k.	10	p.	17
b.	8	g.	4	l.	15	q.	16
c.	1	h.	3	m.	13		
d.	7	i.	9	n.	14		
e.	2	j.	12	o.	11		

2.

a.	3	d.	6
b.	1	e.	2
c.	5	f.	4

3. b, c

4. a. Whether underground or overhead service will be used
   b. Voltage and amperage of service needed
   c. Point at which service conductors are to enter the building
   d. Size of service equipment needed

5. a. Service entrance weatherhead or cap
   b. Service entrance raceway
   c. Service entrance conductors
   d. Hub
   e. Meter base
   f. Line lugs
   g. Load lugs
   h. Grounding electrode conductor
   i. Grounding lugs
   j. Service entrance conductors
   k. Service mast
   l. Service lateral
   m. Roof flashing
   n. Service entrance raceway
   o. Underground service raceway
   p. Load center or panel
   q. Meter

6. a, b, c

7. a, b, c

8. All are correct

9. b, d, e

Answers to Written Test

10.
- a. 1,900
- b. 5,700
- c. 5,700
- d. 47.5
- e. 3
- f. 5,700
- g. 10,200
- h. 10,200
- i. 2,520
- j. 5,520
- k. 13,520
- l. 13,520
- m. 56.3
- n. 5,520
- o. 11,120
- p. 11,120
- q. 46.3

Service
Unit 3

Written Test

Name ____ Score ________________

1. Match the terms on the right with their correct definitions.

______a. Weak link in the circuit that limits the amperage to a specified amount

______b. Supply conductors that extend from the street main or from transformers to the service equipment of the premises to be supplied

______c. An enclosure designed for surface mounting and having swinging doors or covers secured directly to and telescoping with the walls of the box proper

______d. Power conductors coming into building from power company

______e. Service conductors between the terminals of the service equipment and the point of connection to the service lateral

______f. Protective equipment used where the mast emerges from the roof or eave to seal around the raceway and protect against water damage

______g. Service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop

______h. Service conductors made up in the form of a cable

1. Cutout box
2. Service entrance conductors, underground system
3. Service cable
4. Service entrance conductors, overhead system
5. Overcurrent protection
6. Roof flashing
7. Service drop
8. Service conductors

Written Test

______i. A device or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply

______j. Conductor used to connect the grounding electrode to the equipment grounding conductor and/or the grounding conductor of the circuit at the service

______k. The conductors and equipment for delivering energy from the supply system to the wiring system of the premise being served

______l. That portion of the service raceway that extends through a roof or eave

______m. Necessary equipment, usually consisting of a circuit breaker or fuses and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply

______n. Underground service conductors between the street main, including any risers at a pole or other structure or from transformers and the first point of connection to the service entrance conductors in a terminal box or meter or other enclosure with adequate space inside or outside the building wall

______o. Automatic overcurrent device that trips on overloads or shorts and is resettable

______p. Unintentional contact of a conductor

______q. Raceway that encloses the service entrance conductors

9. Disconnecting means
10. Service
11. Circuit breaker
12. Grounding electrode conductor
13. Service equipment
14. Service lateral
15. Service mast
16. Service raceway
17. Short circuit

Written Test

2. Match the required clearances for service drop conductors on the right to their various construction locations.

______a. At the electric service entrance to buildings, or at the drip loop of the building electric entrance, measured from final grade or at the accessible surface

______b. Over a roof with a slope of not less than 4″ in 12″ on systems which do not exceed 300V between conductors

______c. Over residential property

______d. Over public streets, alleys, roads, and nonresidential driveways

______e. If the conductors do not pass over more than 6′ of overhang and are terminated at a through-the-roof raceway or support on a system which does not exceed 300V between conductors

______f. For those areas where the voltage is limited to 300V to ground

1. 3′
2. 18″
3. 10′
4. 12′
5. 15′
6. 18′

3. Select true statements concerning service disconnects by placing an "X" in the blank preceding the true statements.

______a. Not more than seven switches or circuit breakers are allowed in a single enclosure or grouped on a switch board.

______b. The transfer switch must disconnect the main service before connecting the alternate source.

______c. The transfer switch may be manually or automatically operated.

4. List four facts that should be known before the service installation is started.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Written Test

5. Identify the parts of a service entrance.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________

j. ______________________

k. ______________________

l. ______________________

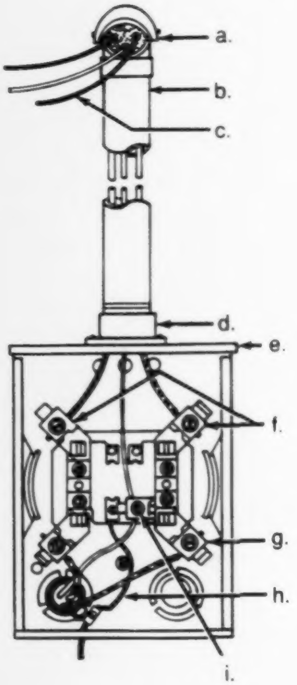
m. ______________________

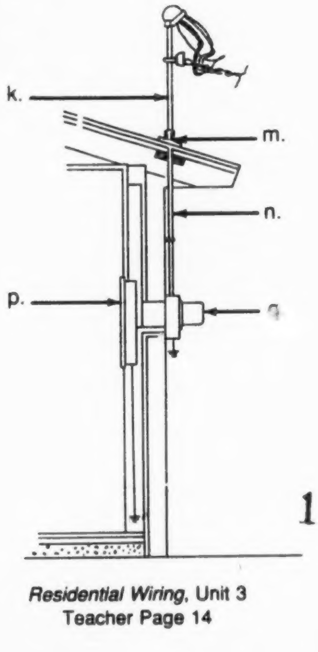
n. ______________________

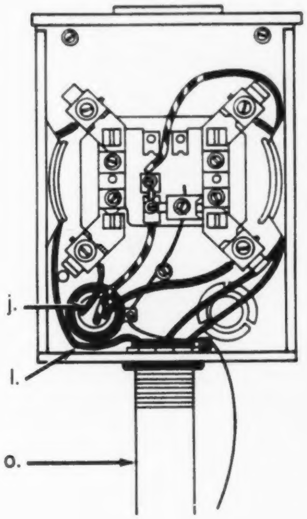
o. ______________________

p. ______________________

q. ______________________







Written Test

6. Select from the following list types of grounding electrodes by placing an "X" in the blanks preceding the correct types.

______a. Water pipe

______b. 8′ length of ⅝″ iron or steel rod

______c. Nearest effectively grounded structural metal member of the structure

______d. 8′ length of ½″ galvanized pipe

______e. At least 10′ of bare copper conductor not smaller than No. 5 AWG or one or more steel reinforced bars or rods of not less than ¾″ diameter encased in at least 2″ of concrete in a foundation or footing

7. Select true statements concerning grounding electrode conductor installations and sizes by placing an "X" in the blanks preceding the true statements.

______a. Conductors and enclosures shall be secured to the surface they follow.

______b. #6 or larger conductors must be in conduit if subject to physical damage.

______c. If free from physical damage, #6 conductors may follow the surface of building if stapled securely.

______d. Aluminum or copper clad aluminum may be used in contact with masonry or earth.

8. Select true statements concerning short circuit protection at service equipment by placing an "X" in the blanks preceding the true statements.

______a. Service equipment must be able to withstand the fault-current that the power company's transformer could deliver in case of a short-circuit condition.

______b. Overcurrent protection devices must be selected to interrupt instantaneous short-circuit currents.

______c. Formulas for short circuit calculations include:

(1) Single phase, $I = \dfrac{KVA \times 1000}{E}$

(2) Three phase, $I = \dfrac{KVA \times 1000}{E \times 1.73}$

Written Test

9. Select true statements concerning surge protection by placing an "X" in the blanks preceding the true statements.

______a. Voltage surges with peaks of several thousand volts, even on 120V circuits, are uncommon.

______b. Surges occur because of induced voltages in power lines resulting from lightning strikes in the vicinity of the line.

______c. Lightning surge arresters allow the passage of current to ground as long as the voltage is normal.

______d. When the voltage rises to a definite amount above normal, the surge arrester must provide a path to ground for discharge of surge energy.

______e. Arresters must not be damaged by the discharge and be capable of automatically repeating thier actions as frequently as is required.

10. Calculate the size of service and minimum number of circuits on the following dwelling.

1,900 sq. ft. with a 12 kw range

General lighting load
a.____________ sq. ft. × 3 watts per sq. ft. = b.____________

Minimum number of branch circuits
General lighting load c.____________ ÷ 120 = d.____________ ÷ 20 = e.____________ or number of general lighting circuits

Small appliance load: Two 2-wire 20 ampere circuits.
Laundry load: One 2-wire 20 ampere circuit.

Minimum size feeders required
Computed load

General lighting	f.____________	watts
Small appliance	+3,000	watts
Laundry	+1,500	watts
Total (without range)	g.____________	watts
3,000 watts at 100% =	3,000	watts
Total (without range) h.____________ – 3,000 = ____________ watts × 35% =	i.____________	watts
Net computed load (without range)	j.____________	watts
Range load	+8,000	watts
Net computed load (with range)	k.____________	watts

For 120/240 volt 3-wire system feeders, net computed load (with range) l.____________ ÷ 240 = m.____________ amperes.

Written Test

Net computed load exceeds 10 kw so service conductors shall be 100 amperes.

Reduced size neutral shall be permitted, usually two trade sizes smaller thatn the ungrounded conductors

Feeder and service neutral
Lighting: Small applicance load (net without range) n.____________ watts
Range load 8,000 watts at 70% +5,600 watts
Total o.____________ watts

Total p.____________ ÷ 240 = q.____________ amperes

*Permission to duplicate this test is granted.

Service
Unit 3

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Calculate Service Size and Minimum Number of Circuits Rating _____

Comments: ____

____

Job Sheet 1—Install an Overhead Raceway With Service Entrance Conductors to a Meter Base Rating _____

Comments: ____

____

Job Sheet 2—Connect Meter Base Assembly to Load Center or Panel Rating _____

Comments: ____

____

Job Sheet 3—Install an Underground Service (Lateral) Raceway With Conductors to a Meter Base Rating _____

Comments: ____

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

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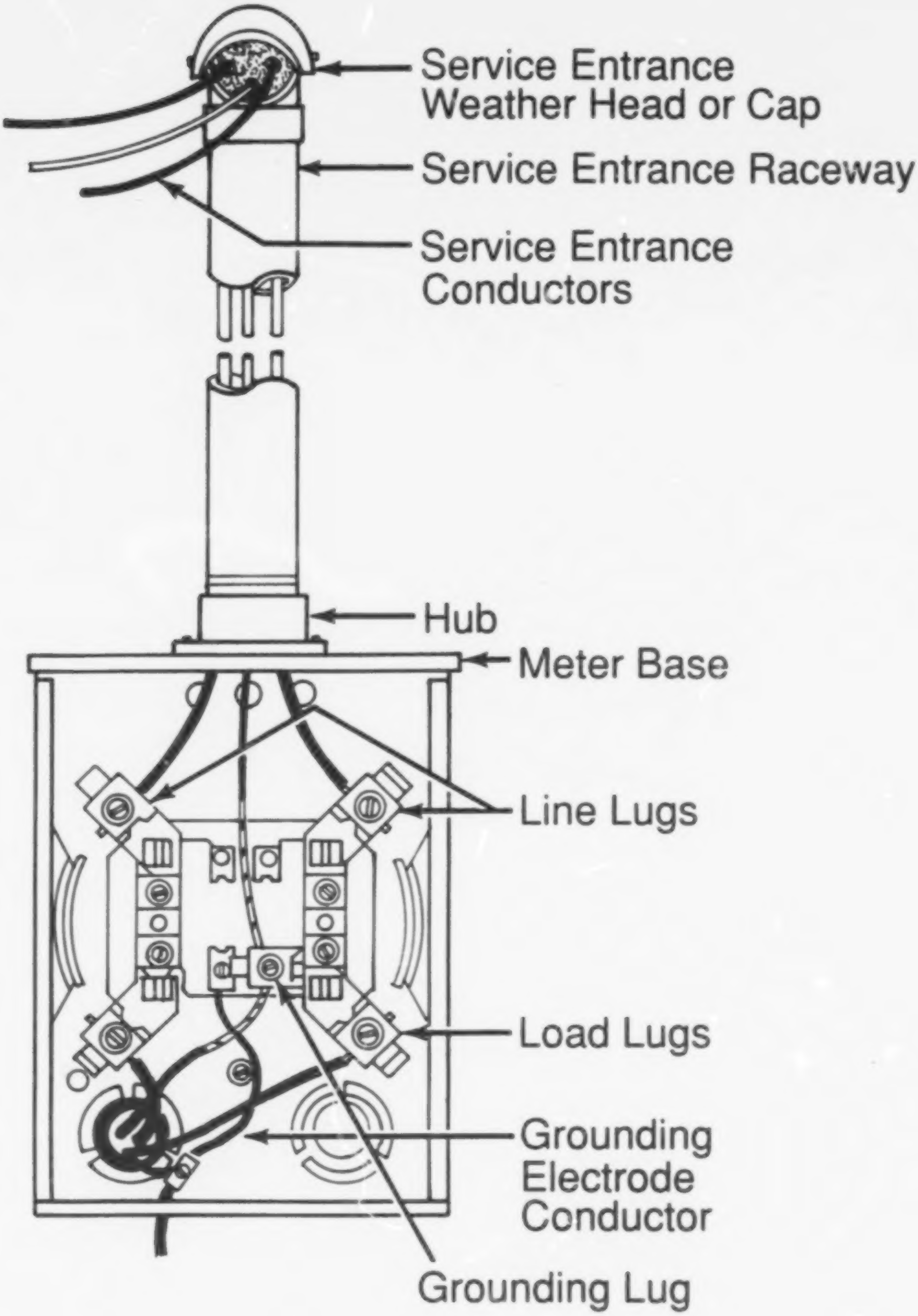
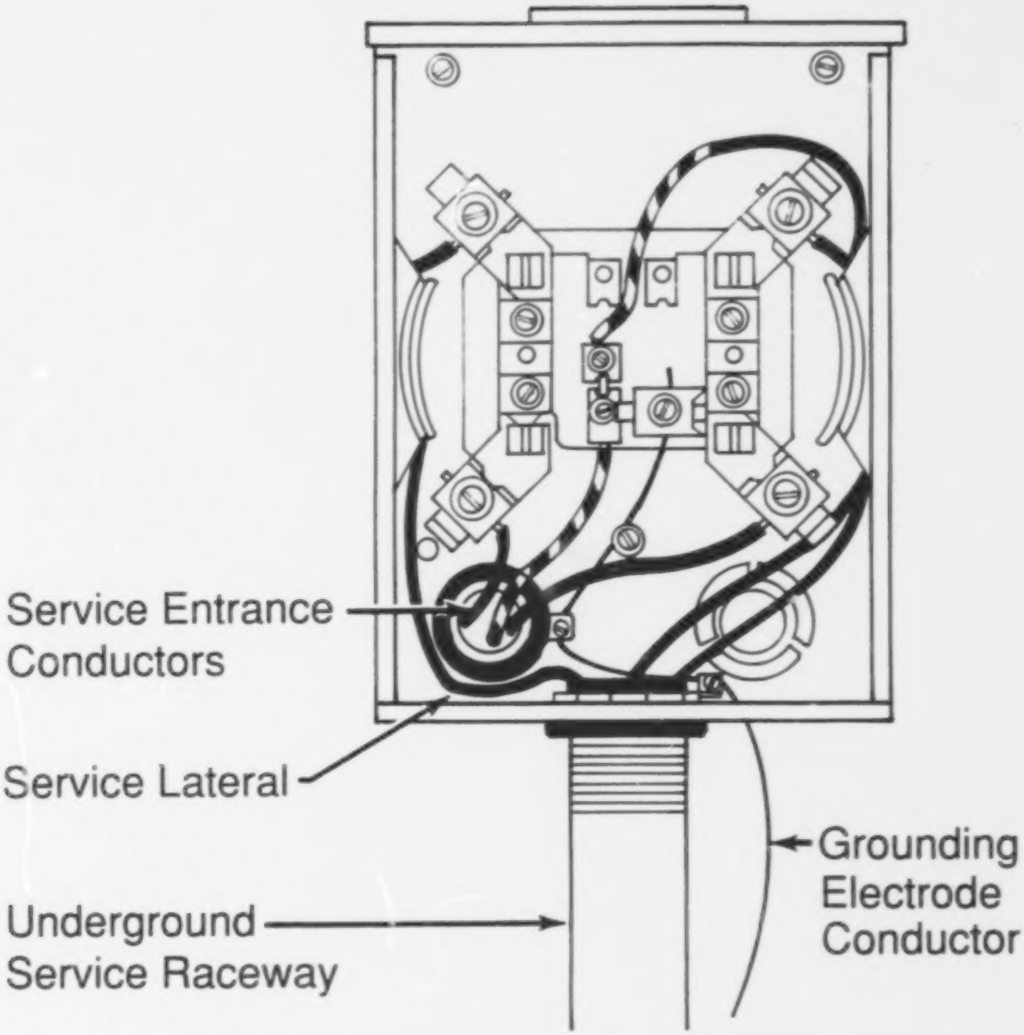
Parts of a Service Entrance



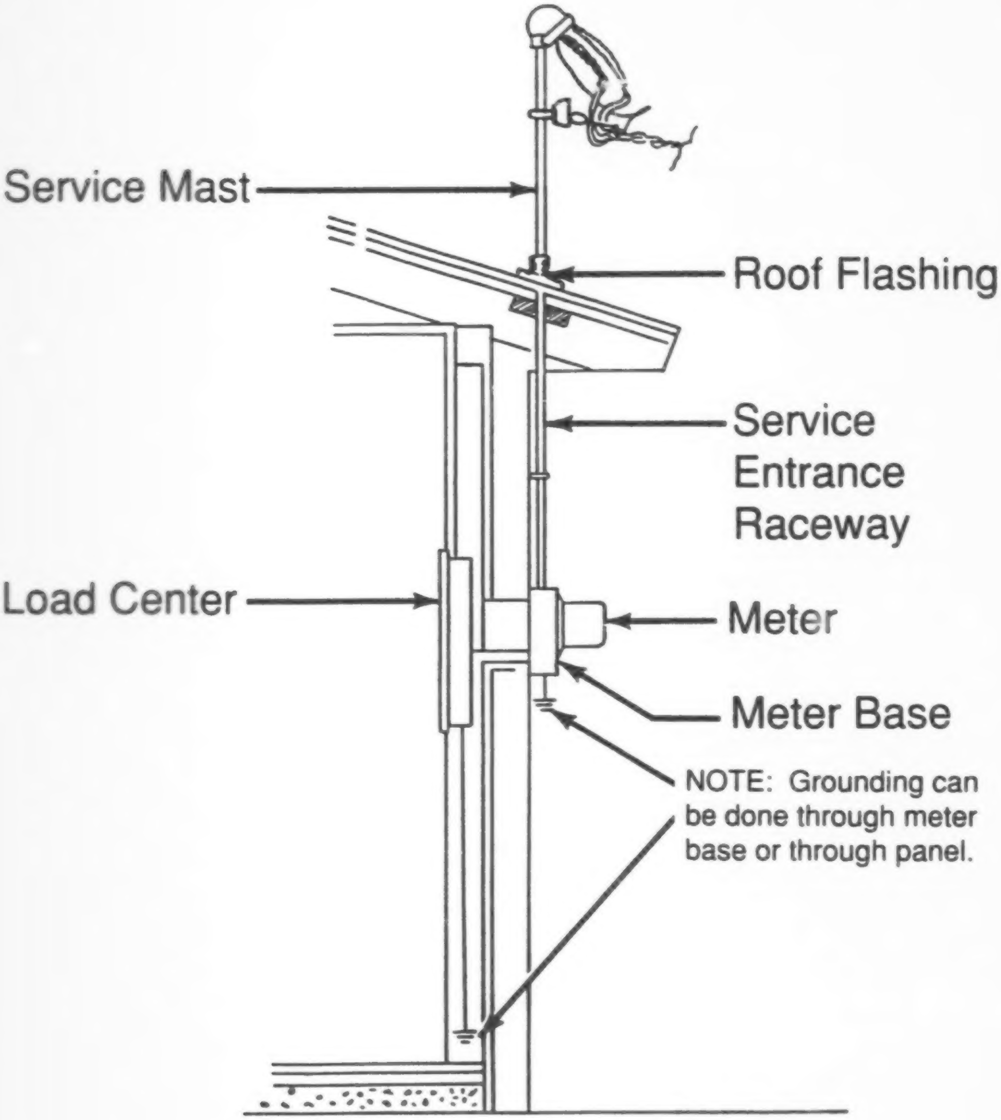
Service Entrance Weather Head or Cap
Service Entrance Raceway
Service Entrance Conductors
Hub
Meter Base
Line Lugs
Load Lugs
Grounding Electrode Conductor
Grounding Lug

Parts of a Service Entrance
(Continued)


Service Entrance Conductors
Service Lateral
Underground Service Raceway
Grounding Electrode Conductor

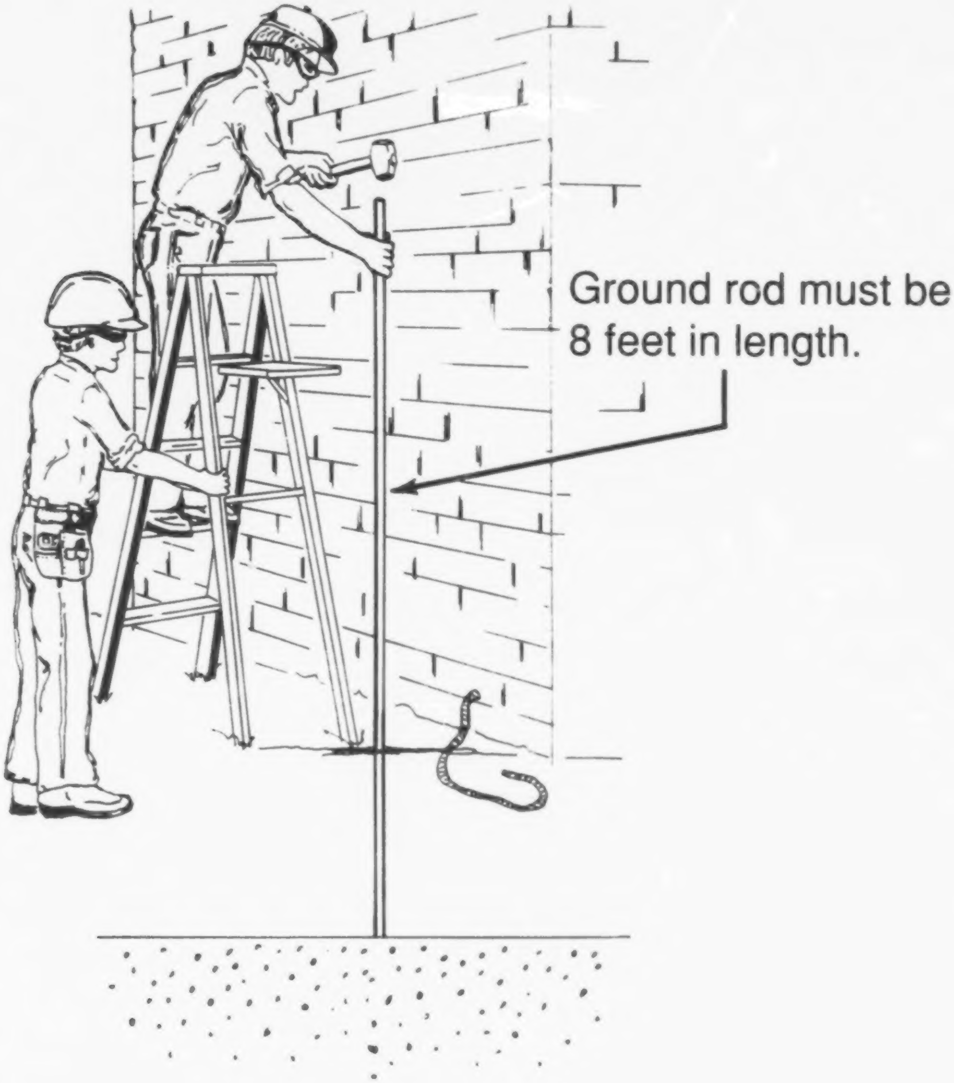
Note: If metal conduit is used, a bonding bushing is required.

Parts of a Service Entrance
(Continued)


Service Mast
Roof Flashing
Service Entrance Raceway
Load Center
Meter
Meter Base
NOTE: Grounding can be done through meter base or through panel.

Note: Check with the local power company for specifications on service mast.

Installing Grounding Rod


Ground rod must be
8 feet in length.

Service
Unit 3

Information Sheet

1. **Terms and definitions**

   a. **Circuit breaker** — Automatic overcurrent device that trips on overloads or shorts and is resettable

   b. **Cutout box** — An enclosure designed for surface mounting and having swinging doors or covers secured directly to and telescoping with the walls of the box proper

   c. **Disconnecting means** — A device or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply

   d. **Grounding electrode conductor** — Conductor used to connect the grounding electrode to the equipment grounding conductor and/or the grounding conductor of the circuit at the service

   e. **Overcurrent protection** — Weak link in the circuit that limits the amperage to a specified amount

   f. **Roof flashing** — Protective equipment used where the mast emerges from the roof or eave to seal around the raceway and protect against water damage

   Note: The majority of the following definitions are from *NEC* Article 100.

   g. **Service** — The conductors and equipment for delivering energy from the supply system to the wiring system of the premise being served

   h. **Service cable** — Service conductors made up in the form of a cable

   i. **Service conductors** — Supply conductors that extend from the street main or from transformers to the service equipment of the premises to be supplied

   j. **Service drop** — Power conductors coming into building from power company

   k. **Service entrance conductors, underground system** — Service conductors between the terminals of the service equipment and the point of connection to the service lateral

   l. **Service entrance conductors, overhead system** — Service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop

Information Sheet

m. **Service equipment** — Necessary equipment, usually consisting of a circuit breaker or fuses and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply

Note: Overcurrent devices shall not be located in the vicinity of easily ignitable material such as in clothes closets.

n. **Service lateral** — Underground service conductors between the street main, including any risers at a pole or other structure or from transformers and the first point of connection to the service entrance conductors in a terminal box or meter or other enclosure with adequate space inside or outside the building wall

Note: Where there is no terminal box, meter, or other enclosure with adequate space, the point of connection shall be considered to the point of entrance of the service conductors into the building.

o. **Service mast** — That portion of the service raceway that extends through a roof or eave

p. **Service raceway** — Raceway that encloses the service entrance conductors

q. **Short circuit** — Unintentional contact of a conductor

2. **Clearances for service drop conductors not in excess of 600v**

Note: *NEC* Art: 230-24 deals with clearances.

a. Over roofs — Not less than 8′ from highest point except where the voltage between conductors does not exceed 600 and:

- If the roof has a slope of not less than 4″ in 12″, a 3′ minimum is permitted on systems which do not exceed 300v between conductors
- If the conductors do not pass over more than 6′ of overhang and are terminated at a through-the-roof raceway or support, an 18″ minimum is permitted on systems which do not exceed 300v between conductors

  Note: Refer to *NEC* Art: 230-24(a) exception 3.

b. From ground vertically

- 10 feet — At the electric service entrance to buildings, or at the drip loop of the building electric entrance, measured from final grade or other accessible surface only for service-drop cables supported on and cabled together with a grounded bare messenger and limited to 150 volts to ground

Information Sheet

- 12 feet — For those areas where the voltage is limited to 300V to ground
- 15 feet — Over residential property
- 18 feet — Over public streets, alleys, roads, parking areas subject to truck traffic, driveways on other than residential property, and other land traversed by vehicles such as cultivated, grazing, forest, and orchard

3. Service disconnects

a. Maximum number of service entrance disconnects — Not more than six switches or circuit breakers in single enclosures or grouped on a switchboard.

Note: *NEC* Art: 230 deals with services. Where a residence requires more than six circuits, a main breaker is generally used.

b. Transfer switches — A double throw switch is used to transfer the alternate source of supply in case main service is lost. The transfer switch must disconnect the main service before connecting the alternate source. This switch may be manually or automatically operated.

Note: *NEC* Art: 230-83 deals with transfer switches.

4. Facts that should be known before the service installation is started

a. Whether underground or overhead service will be used

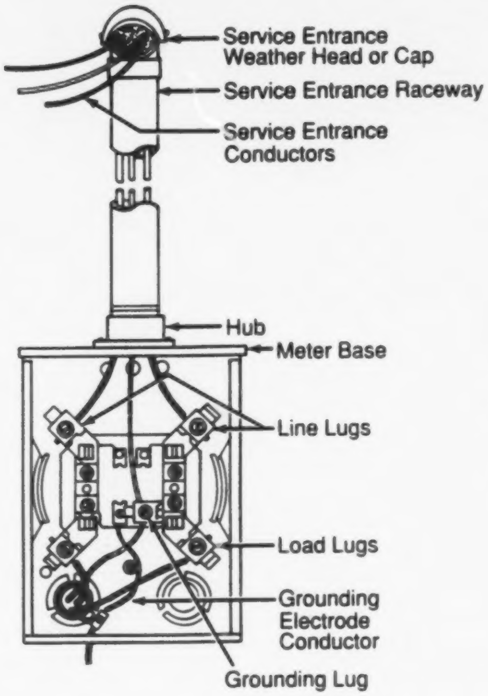
b. Voltage and amperage of service needed

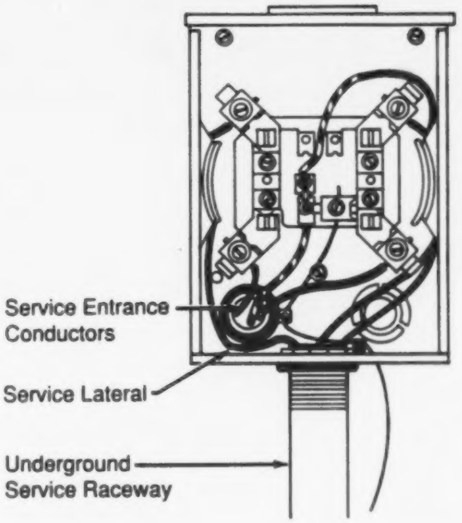
c. Point at which service conductors are to enter the building

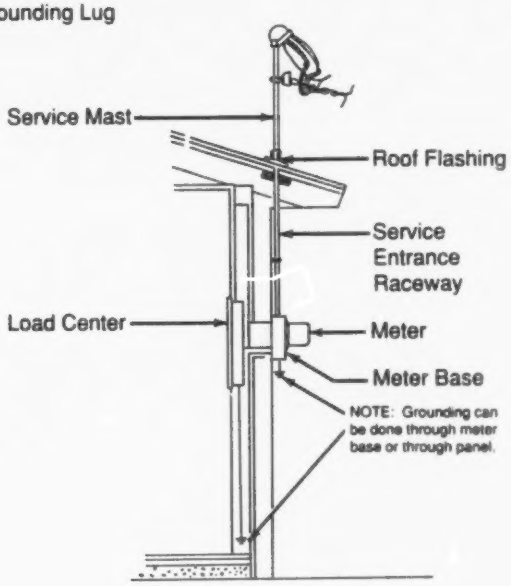
d. Size of service equipment needed

Information Sheet

5. Parts of a service entrance


Service Entrance Weather Head or Cap
Service Entrance Raceway
Service Entrance Conductors
Hub
Meter Base
Line Lugs
Load Lugs
Grounding Electrode Conductor
Grounding Lug


Service Entrance Conductors
Service Lateral
Underground Service Raceway


Service Mast
Roof Flashing
Service Entrance Raceway
Load Center
Meter
Meter Base
NOTE: Grounding can be done through meter base or through panel.

Information Sheet

6. Types of grounding electrodes

Note: *NEC* Art: 250 deals with grounding.

a. Structural metal — Nearest available effectively grounded structural metal member of the structure

b. Water pipe — Metal water pipe for the first five feet from supply shall be used when available

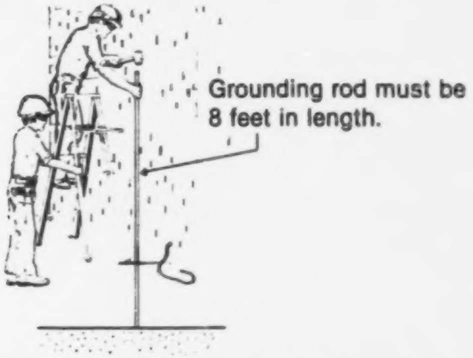
Note: It should be in direct contact with earth for 10 feet or more and electrically continuous to the points of connection of the grounding electrode conductor and the bonding conductors. Refer to *NEC* Art: 250-82(a).

c. Concrete encased electrodes — At least 20′ of bare copper conductor not smaller than No. 4 AWG or one or more steel reinforced bars or rods of not less than ½″ diameter encased in at least 2″ of concrete in a foundation or footing

d. Made electrodes

Note: Refer to *NEC* Art: 250-83.

- 8′ lengths of:
  - ¾″ galvanized pipe
  - ⅝″ iron or steel rod
  - ½″ nonferrous rod (listed copper, brass, stainless steel, and other noncorrosive metals)
- Plate electrodes — Not less than 2′ square



Note: Where a rock bottom is not encounterd the electrode shall be driven to a length of 8′. Where rock is hit at less than 4′ the electrode shall be buried in a trench. A metal underground water pipe shall be supplemented by an additional electrode as specified in *NEC* Articles 250-81 or 250-3.

Information Sheet

7. Grounding electrode conductor installations and sizes

Note: *NEC* Article 250 deals with grounding.

a. Conductors and enclosures shall be secured to the surface they follow.

b. #6 or larger conductors

- Must be in conduit if subject to physical damage.
- If free from physical damage, it may follow the surface of building if stapled securely.
- Aluminum or copper clad aluminum cannot be used in contact with masonry or earth.

Note: Grounding electrode conductor sizes are determined by referring to *NEC* Table 250-94.

8. Short circuit protection at service equipment

a. Service equipment must be able to withstand the fault-current that the power company's transformer could deliver in case of a short-circuit condition.

b. Overcurrent protection devices must be selected to interrupt instantaneous short-circuit currents (fault currents).

Note: The following table represents the "Rule of Thumb" method for finding IC (interrupting capacity) ratings for fuses or circuit breakers. Check with your local power company.

Ampacity of Service	Service Rating	IC Rating
120/240V 1 Ph	Less than 200 A	10,000 A
120-240V 1 Ph	Less than 600 A	42,000 A
120-240V 3 Ph	Less than 2000 A	42,000 A

c. Formulas for short circuit calculations include:

- Single phase, $I = \frac{KVA \times 1000}{E}$
- Three phase, $I = \frac{KVA \times 1000}{E \times 1.73}$

Information Sheet

9. Surge protection

a. Voltage surges with peaks of several thousand volts, even on 120V circuits, are not uncommon. These surges occur because of induced voltages in power lines resulting from lightning strikes in the vicinity of the line. Surge arresters for installation as part of an electric service and for use with cord-and-plug-connected electronic equipment are commercially available.

b. Lightning surge arresters must fulfill the following functions:

- They must not allow the passage of current to ground as long as the voltage is normal.
- When the voltage rises to a definite amount above normal, they must provide a path to ground for discharge of surge energy.
- As soon as the voltage has returned below the setting of the arrester the arrester must stop the flow of current to ground and re-insulate itself so as to insulate the supply conductor from ground.
- Arresters must not be damaged by the discharge and be capable of automatically repeating their actions as frequently as is required.

10. Sizing the service entrance conductors

Note: In Unit 1, Blueprint Reading and Load Calculations, we learned the procedure for various circuit calculations. It is now necessary to carry those calculations one step further to determine the size of service entrance conductors.

a. Using the examples shown below, determine the size of the service entrance required for the described dwelling.

PROBLEM: Determine the size service-entrance conductors required for Phases A and B and the neutral of a 2,000 sq. ft. dwelling unit with the following loads:

- General lighting and receptacle loads
- Two small appliance loads and one laundry load
- Special appliance loads

Two wall-mounted 4kVA ovens	8,000 VA
Cooktop	6,500 VA
Heating	25,000 VA
Air conditioning	9,000 VA
Water heater	5,000 VA
Dishwasher	1,200 VA
Disposal	1,000 VA

Information Sheet

OTHER LOADS

Step 1: *Table 220-30.*

General lighting and receptacle loads:
2,000 sq. ft. × 3 VA = **6,000 VA**

Small appliance loads:
1,500 VA × 2 = **3,000 VA**

Laundry load:
1,500 VA × 1 = **1,500 VA**

Wall-mounted ovens:
4 kVA × 2 = **8,000 VA**

Cooktop = **6,500 VA**

Water heater = **5,000 VA**

Dishwasher = **1,200 VA**

Disposal = **1,000 VA**

Total loads = **32,200 VA**

ANSWER: The other loads are 32,200 volt-amps.

HEATING LOAD

Step 1: *220-21*

Drop smallest of heating or air conditioning load

ANSWER: The heating load is 25,000 volt-amps.

APPLYING DEMAND FACTORS
Other loads

Step 1: *Table 220-30.*

First 10,000 VA at 100% = 10,000 VA
Next 22,200 VA at 40% = 8,800 VA

ANSWER: The demand load is **18,880 volt-amps**.

Information Sheet

Heating load

Step 1: *Table 220-30.*

25,000 VA × 65% = **16,250 VA**

ANSWER: The demand load is **16,250 volt-amps**.

Step 1: Add all loads

Other loads = 18,800 VA
Heating load = 16,250 VA

18,800 VA + 16,250 VA = **35,130 VA**

b. Take the total connected demand load of 35,130 VA and divide it by the voltage.

$$\frac{35{,}130 \text{ VA}}{240 \text{ Volts}} = 146 \text{ Amps}$$

c. Go to Table 310-16, Column 2 of the *NEC* to find that 2 #1/0 THW copper conductors are required. The neutral loads should now be determined. See example.

TOTAL NEUTRAL LOADS

Step 1:

220-22. General lighting and receptacle loads:
6,000 VA

220-16(a,b). Small appliance loads: **4,500 VA**
4,500 VA

6,000 VA + 4,500 VA = 10,500 VA

General lighting and receptacle loads and small appliance loads: **10,500 VA**

Table 220-11. First 3,000 VA at 100% = 3,000 VA
Next 7,500 VA at 35% = 2,625 VA

3,000 VA + 2,625 VA = **5,625 VA**

Table 220-19, Column C. Cooking Equipment

14,500 VA × 55% = 7,975 VA

220-22. 7,975 VA × 70% = **5,583 VA**

220-3(c)(1). Dishwasher = **1,200 VA**
220-3(c)(2). Disposal = **1,000 VA**

Information Sheet

220-14. Largest motor × 25%
1,000 VA × 25% = **250 VA**

Total neutral loads = **13,658 VA**

Step 2: $I = \frac{VA}{V}$

$$I = \frac{13{,}658\ VA}{240\ V} = 57\ A$$

ANSWER: The neutral load is 57 amps.

d. Size of the service entrance conductors required for this dwelling are:

- Phases A and B:
  Table 310-16, Column 2: Two #1/0 THW copper conductors are required.
- Neutral:
  Table 310-16, Column 2: One #6 THW copper conductor is required.

  Note: Note 3 to *NEC* Tables 310-16-310-31 may be applied.

Service
Unit 3

Assignment Sheet 1—Calculate Service Size and Minimum Number of Circuits

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Complied with *NEC*	______
Calculated service size correctly	______
Calculated number of circuits correctly	______

Directions: Using the standard code procedure listed below, calculate service size and minimum number of circuits on the following single family dwelling.

Note: Refer to *NEC* Chapter 9 — Tables and Examples. Example No. 1(a).

Dwelling has a floor space of 2,100 square feet. It also has an 11 kw electric range.

General lighting load
1.____________ sq. ft. × 3 watts per sq. ft. = 2.____________

Minimum number of branch circuits
General lighting load 3.____________ ÷ 115 = 4.____________ ÷ 20 =
5.____________ or number of general lighting circuits

Note: This number always rounds to next whole number if a fraction appears.

Small appliance load: Two 2-wire 20 ampere circuits.
Laundry load: One 2-wire 20 ampere circuit.

Minimum size feeders required
Computed load

General lighting	6.____________	watts
Small appliance	+3,000	watts
Laundry	+1,500	watts
Total (without range)	7.____________	watts
3,000 watts at 100% =	3,000	watts
Total (without range) 8.____________ – 3,000 = ____________ watts × 35% =	9.____________	watts
Net computed load (without range)	10.____________	watts
Range load	8,000	watts
Net computed load (with range)	11.____________	watts

Assignment Sheet 1

For 120/240 volt 2-wire system feeders, net computed load (with range) 12.____________ ÷ 240 = 13.____________ amperes.

Net computed load exceeds 10 kw so service conductors shall be 100 amperes.

Reduced size neutral shall be permitted, usually two trade sizes smaller than the ungrounded conductors.

Feeder and service neutral
Lighting: Small applicance load (net without range) 14.____________ watts
Range load 8,000 watts at 70% 5,600 watts
Total 15.____________ watts
Total 16.____________ ÷ 240 = 17.____________ amperes

Note: Refer to *NEC* Table 310-16, notes to Tables - No. 3, for proper conductor sizing.

Service
Unit 3

Job Sheet 1—Install an Overhead Raceway With Service Entrance Conductors to a Meter Base

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
Service mast straight and tight	______
Service conductor formed properly	______
Service conductors extend beyond riser cap proper length	______
Proper connection of line conductor to supply lugs	______
Proper connection of neutral conductor to neutral lugs	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

- Flat blade screwdriver
- Lineworker's pliers
- Hammer
- Knife
- Hacksaw
- Folding rule with sliding scale
- Meter base
- Service entrance cap (1½″ clamp-on type)
- 3′ of 1½″ rigid metal conduit (threaded on one end)
- 12′ of #2 copper TW (two 6′ pieces)
- 6′ of #4 copper
- Safety glasses

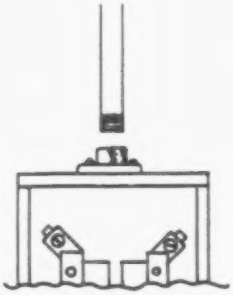
B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

Job Sheet 1

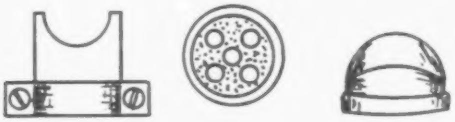
☐ 2. Screw threaded end of raceway into hub.

Figure 1



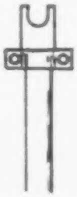
☐ 3. Remove cover and separator from weatherhead.

Figure 2



☐ 4. Clamp weatherhead base onto the end of the service raceway.

Figure 3



☐ 5. Install conductors in the raceway.

Note: Start at weatherhead end.

☐ 6. Connect grounded conductor to grounding lug.

Note: When possible, leave grounded conductor long enough to connect to disconnect equipment grounding bar.

☐ 7. Remove 1″ to 1½″ of insulation from ungrounded conductors and connect to line lugs.

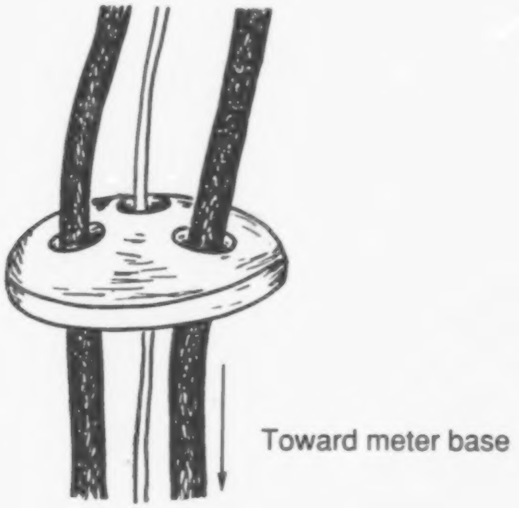
☐ 8. Knock out three outlined holes in the entrance cap separator.

Job Sheet 1

☐ 9. Put grounded conductor through center hole.

☐ 10. Put ungrounded conductors through side holes.

Figure 4



☐ 11. Gently start forming conductors so the separator will fit back in the base.

Note: Care must be taken while you are bending the curvature in the conductors to prevent damage to the plastic conductor separator.

☐ 12. Replace service entrance cap cover.

☐ 13. Have instructor check your work.

☐ 14. Clean work area and put away all equipment and materials.

Evaluator's comments: ______________________________

____

____

Service
Unit 3

Job Sheet 2—Connect Meter Base Assembly to Load Center or Panel

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
Meter base is straight and level	______
Raceway is mounted securely	______
Correct connection made (ungrounded conductor to ungrounded [top] lugs)	______
Correct connection made (grounded conductor to grounded lug)	______
All conductors formed correctly	______
All connections secure	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

Screwdriver
Lineworker's pliers
Hammer
Knife
Level
Rule
Awl
Meter base assembly from Job Sheet 1
Two 1¼″ insulating bushings
Four 1¼″ locknuts
One 1¼″ reamed nipple long enough to connect meter base to distribution panel

Note: Nipple, bushings, and locknuts can be larger than 1¼″ if conductor size or necessity mandates.

#4 copper (1 piece)
#2 TW copper (2 pieces)
Eight 1″ #12 metal tapping screws
One 100 amp 1 phase 3 wire SN. load center
One 1½″ rigid conduit strap
2″ × 4″ mock up wall or roughed in residential dwelling
Safety glasses

Job Sheet 2

B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

☐ 2. Mount load center between studs with metal tapping screws.

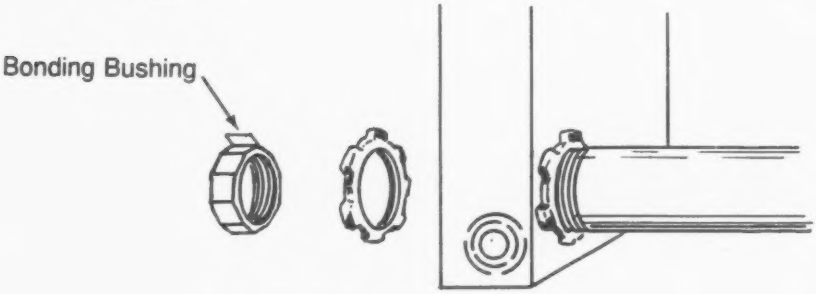
Note: Panel height should be adjusted so that knockouts will line up with meter base between 5′ and 6′. The utility company will give you their recommended height.

☐ 3. Remove load center knockout that will align with meter base at correct height.

☐ 4. Install nipple in opening with a locknut on the backside of load center and a locknut and bushing on the inside. (Figure 1)

Note: Be sure that locknuts are installed tightly with teeth into the metal. Also be sure to check local codes on bonding.

Figure 1



☐ 5. Remove appropriate knockout from meter base.

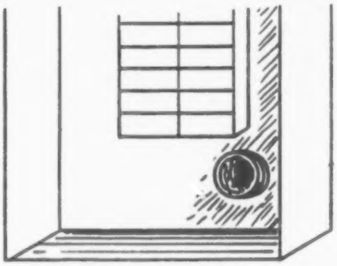
☐ 6. Put back up locknut for meter base on nipple.

Job Sheet 2

☐ 7. Place nipple through meter base knockout and secure loosely with one screw.

Note: Cut off excess nipple; leave only what is needed for locknut and bushing.

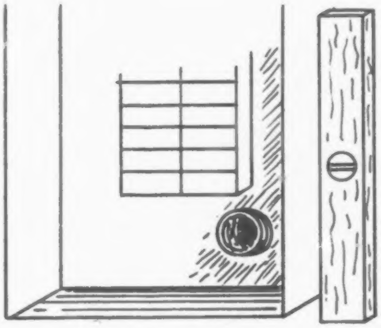
Figure 2



☐ 8. Install internal locknut and bushing.

☐ 9. Place level on side of meter base and secure with mounting screws when leveled.

Figure 3



☐ 10. Put level on service raceway and secure with strap when leveled.

☐ 11. Install grounded conductor in nipple and connect to meter base and load center grounded lugs.

Note: Make all bends in conductors as square as possible while maintaining a radius equal to at least five times the diameter. Make sure you stay as far as possible from load and line lugs in your routing of the gounded conductors.

Job Sheet 2

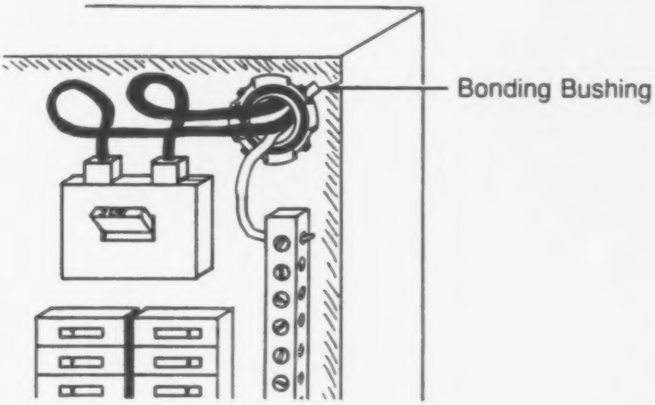
☐ 12. Install ungrounded conductors in nipple.

☐ 13. Strip about 1½" insulation from each of the ungrounded conductors, form them, and connect to meter load lugs.

☐ 14. Form ungrounded conductors in load center.

☐ 15. Cut off excess and connect to load center line lugs.

Figure 4



Note: The service system is still without a grounding electrode conductor. This conductor can originate at the load center or in the meter base. It can terminate at a cold water pipe or made electrode.

☐ 16. Have instructor check your work.

☐ 17. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Service
Unit 3

Job Sheet 3—Install an Underground Service (Lateral) Raceway with Conductors to a Meter Base

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Assembly mount at proper height	______
Correct connections made (ungrounded conductor to ungrounded lugs and main breaker)	______
Correct connections made (grounded conductor to grounded lugs in panel and meter base)	______
All threaded connections tight	______
All conductor connections secure	______
Assembly level and straight	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

- Flat blade screwdriver
- Lineworker's screwdriver
- Knife
- Hacksaw
- Folding rule or tape measure
- Meter base
- 3′ of 2″ rigid nonmetallic tubing (PVC)
- One — 2″ PVC 90° elbow
- One — 2″ PVC coupling
- One — 2″ PVC male adapter
- One — 2″ lock nut
- 10′ of 3 conductor #1/0 use (underground service entrance, suitable for direct burial)
- Safety glasses

Job Sheet 3

B. Procedure

☐ 1. Put on safety glasses and gather equipment and materials.

☐ 2. Mount meterbase.

Note: Meter base height should be adjusted to conform with local utility company requirements. (See your instructor.)

☐ 3. Install PVC 90° elbow onto 2″ conduit, using the 2″ coupling.

Note: For the purpose of this procedure it will not be necessary to use the PVC cement to bond the parts together.

☐ 4. Measure the assembled conduit to fit the bottom of the meter base.

Note: Deduct approximately ¼″ for the space needed by the male adapter.

☐ 5. Cut off excess conduit from opposite end of 90° elbow.

☐ 6. Install male adapter onto conduit.

☐ 7. Remove knock-out in bottom of meter base (only 2″).

☐ 8. Install conduit assembly (conduit, male adapter, coupling, and 90° elbow) into meter base knock-out.

☐ 9. Install locknut onto male adapter threads inside meter base and tighten.

Note: Be sure teeth of locknut are turned into metal.

☐ 10. Feed conductors up through raceway into meter base.

☐ 11. Strip approximately 1-1½″ of insulation from each of the ungrounded conductors.

Note: Ground conductor of 3 wire USE cable will be marked with a white or yellow stripe.

☐ 12. Form and install ungrounded conductor to the line legs of meter base.

Note: Supply conductors always attach to the line lugs of a meter base. With underground service installation these conductors must form through the meter base and connect to the top line lugs. **NEVER** attach supply conductors to the bottom lugs; these are for load conductors only.

Job Sheet 3

☐ 13. Strip form and install the grounded conductor.

Note: This conductor should be formed through the meter base and attached to the top lug of the grounded terminal in the meter base.

Note: This service is still without a grounding electrode conductor. This conductor can originate at the load center or in the meter base. It can terminate at a cold winter pipe or made electrode. Consult local inspection authority for requirements or see your instructor.

☐ 14. Have instructor check your work.

☐ 15. Clean work area and put away all equipment and materials.

Evaluator's comments: ____________________

____

____

Trim Out and Troubleshooting
Unit 4

Objective Sheet

Unit Objective

After completing this unit, the student should be able to perform trim out for a residential wiring system and troubleshoot electrical problems for new and existing dwellings. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to trim out and troubleshooting with their correct definitions.
2. Identify common residential receptacle types and cover plates.
3. Identify common residential switch types and cover plates.
4. Match common residential fixture locations with their types.
5. Match appliance classifications with their descriptions.
6. Distinguish between requirements for appliance disconnect means.
7. State the grounding requirements for appliances.
8. Identify the parts of a duplex grounding type receptacle.
9. Identify the parts of an equipment grounding system.
10. Arrange in order the steps for panel trim out.
11. Select true statements concerning troubleshooting procedures.
12. Install a duplex grounding type receptacle. (Job Sheet 1)
13. Install a range or dryer receptacle. (Job Sheet 2)
14. Install a multi-circuit split-wired duplex grounding type receptacle. (Job Sheet 3)
15. Wire a receptacle fed from a lighting outlet through a single pole switch. (Job Sheet 4)

Objective Sheet

16. Connect a supply cord to a free standing range. (Job Sheet 5)
17. Install a fixed appliance equipped with a pigtail to a branch circuit. (Job Sheet 6)
18. Install a fusible safety switch for an air-conditioning condenser. (Job Sheet 7)
19. Troubleshoot an electrical system problem. (Job Sheet 8)

Trim Out and Troubleshooting
Unit 4

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Parts of a Duplex Grounding Type Receptacle (Objective 8)
   TM 2--Equipment Grounding Circuit (Objective 9)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
6. Develop teaching plan. Adjust for different learning styles.
7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.
9. Discuss unit and specific objectives.
10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
11. Discuss and demonstrate the procedures outline in the job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Record job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Design and construct a problem board that will facilitate set up and diagnosis of circuit malfunctions.

2. Contact local electricians and invite them to class to show examples of troubleshooting techniques they employ. Also have them share some of their toughest troubleshooting problems and the outcomes. Have students take notes, then provide a question and answer session for students to ask questions concerning troubleshooting. Skill areas: **listening, writing, and oral communication**.

3. Design and construct work boards for students to use in their performance of the job sheets included in this unit.

4. Collect used appliances from equipment dealers or through private donations for use in completing job sheets in this unit.

5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.

Suggested Activities

Resources Used in Developing This Unit

1. Gebert, Kenneth L. *Blueprint Reading*, 9th ed. Alsip, IL: American Technical Publishers, Inc., 1983.
2. Gray, Elliot C., Jr. and Melbourne E. Bailey. *Electrical Construction and Maintenance Techniques*. Englewood Cliffs, NJ: Prentice-Hall, 1986.
3. Hunzicker Brothers Catalog. Oklahoma City, OK.
4. Mullin, Ray C. *Electrical Wiring: Residential*, 11th ed. Albany, NY: Delmar Publishers Inc., 1993.
5. *1993 National Electrical Code®*. Quincy, MA: National Fire Protection Association, 1992.
6. Taylor, Mark. *Residential Wiring*. Revised. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

Suggested Supplemental Resources

Publications

1. Holzman, Harvey N. *Modern Residential Wiring*. Goodheart-Willcox, 1991.
2. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code®*. Albany, NY: Delmar Publishers Inc., 1993.

Films

1. *Electrical Wiring and Wiring a House*. OCA Educational Products, 424 Valley Road, Warrington, PA 18976.
2. *Residential Electrical Wiring Explained #804* and *Electrical Wiring Explained #803*. Bergwall Productions, Inc., 839 Stewart Avenue, Gordon City, NY 11530.

Suggested Activities

Instructions for Evaluating Student Performance

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Trim Out and Troubleshooting
Unit 4

Answers to Written Test

1. a. 4
   b. 7
   c. 1
   d. 9
   e. 2
   f. 11
   g. 5
   h. 3
   i. 10
   j. 6
   k. 8
   l. 12
   m. 24
   n. 18
   o. 14
   p. 16
   q. 15
   r. 21
   s. 23
   t. 13
   u. 17
   v. 20
   w. 22
   x. 25
   y. 19

2. a. Duplex grounding receptacle
   b. Dual voltage receptacle
   c. Air conditioner receptacle, 20 amp
   d. Air conditioner receptacle, 30 amp
   e. Range receptacle
   f. Dryer receptacle
   g. Switch and receptacle
   h. Ground fault receptacle
   i. Ground fault circuit breaker

3. a. Single pole
   b. Double pole
   c. Three way
   d. Four way
   e. Duplex switch
   f. Switch and pilot light
   g. Dimmer
   h. Timer switch
   i. Photo cell

4. a. 5
   b. 2
   c. 4
   d. 1
   e. 3
   f. 6

5. a. 2
   b. 5
   c. 4
   d. 3
   e. 1

6. b

7. Appliances with exposed noncurrent carrying metal parts likely to become energized shall be grounded.

Answers to Written Test

8. a. Mounting hole
   b. Mounting bracket
   c. Live slot
   d. Live terminals
   e. Cover mounting screw
   f. Ground slot
   g. Grounding terminal
   h. Neutral terminals
   i. Bridge
   j. Neutral slot

9. a. Grounding connection at frame
   b. Receptacle grounding slot
   c. Attachment cap grounding prong
   d. Neutral block
   e. Grounding electrode conductor
   f. Grounding electrode
   g. Grounding conductor

10. a. 3
    b. 4
    c. 1
    d. 5
    e. 2

11. a, c, e, f

Trim Out and Troubleshooting
Unit 4

Written Test

Name ________________________________ Score ______________

1. Match the terms on the right with their correct definitions.

______a. Conductor that carries electrical energy from the switch to the load

______b. The use of a box for splicing or rerouting conductors to get to another location

______c. Utilization equipment, generally other than industrial, normally built in standardized sizes or types, which is installed or connected as a unit to perform one or more functions such as clothes washing, air conditioning, food mixing, or deep frying

______d. A single yoke device with two or more receptacles

______e. The systematic diagnosis of a malfunction

______f. Conductors between light and switch when supply enters the light

______g. A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply

______h. Point of attachment for conductors

______i. Metal strip containing one or more devices

______j. A single yoke device with two grounding type receptacles

______k. Transfer conductors in a switching situation; they are used between 3-ways and 4-ways

1. Appliance
2. Troubleshooting
3. Terminal
4. Switch leg
5. Disconnecting means
6. Duplex grounding receptacle
7. Feed through
8. Traveler
9. Multiple receptacle
10. Strap or yoke
11. Switch loop

Written Test

______l. Receptacle that has had a connecting fin removed for remote control or separate circuit connections

______m. Voltage multiplied times amperage

______n. Unit of an electrical system which is intended to carry but not utilize electrical energy

______o. Detachable design feature that makes terminals common connections

______p. Conductor that supplies electrical energy to a switch

______q. Current carrying conductors, both grounded and ungrounded, on a receptacle switch or overcurrent device

______r. Branch circuit that supplies only one piece of utilization equipment

______s. A 120V branch circuit rated at 1500 VA (20 amps) supplying energy to one or more outlets to which appliances are to be connected

______t. Splicing technique that leaves an accessible conductor for termination at a device, load, or grounding terminal

______u. Device used to open or transfer circuit direction

______v. Piece of equipment used to secure cables

______w. Final stage in a residential wiring project; involves devices and plates, connecting and securing equipment, hanging fixture, and testing the system

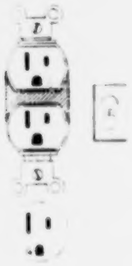
______x. Current carrying conductors and grounding conductors

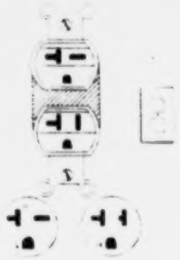
______y. A single contact device with no other contact device on the same yoke

12. Split-wired receptacle
13. Pigtail
14. Receptacle connecting fin
15. Poles
16. Line leg
17. Switch
18. Device
19. Single receptacle
20. Cable clamp
21. Individual branch circuit
22. Trim out
23. Appliance branch circuit
24. Volt ampere
25. Wires

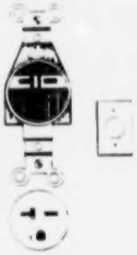
Written Test

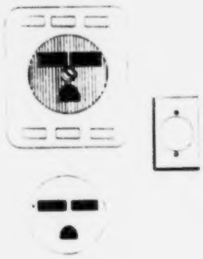
2. Identify common residential receptacle types and cover plates shown below.



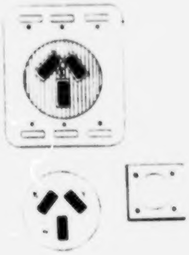


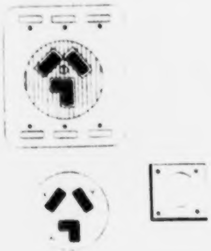
a. ______________________________ b. ______________________________





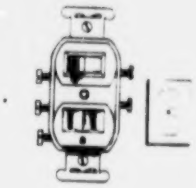
c. ______________________________ d. ______________________________



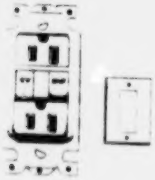


e. ______________________________ f. ______________________________

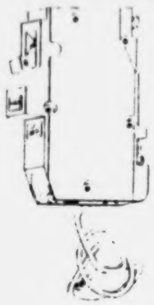
Written Test



g. ______________________________

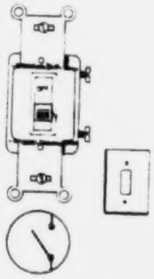


h. ______________________________

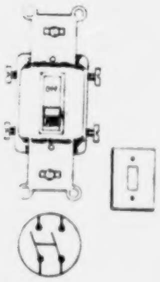


i. ______________________________

3. Identify common residential switch types and cover plates shown below.

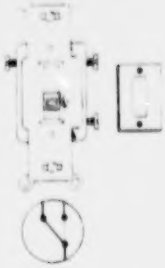


a. ______________________________

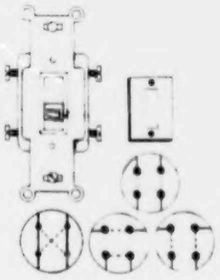


b. ______________________________

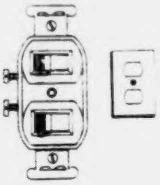
Written Test



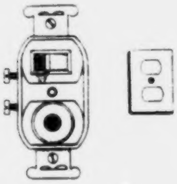
c. ______________________________



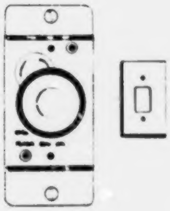
d. ______________________________



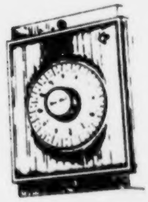
e. ______________________________



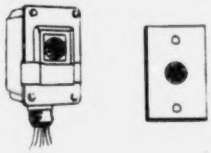
f. ______________________________



g. ______________________________



h. ______________________________

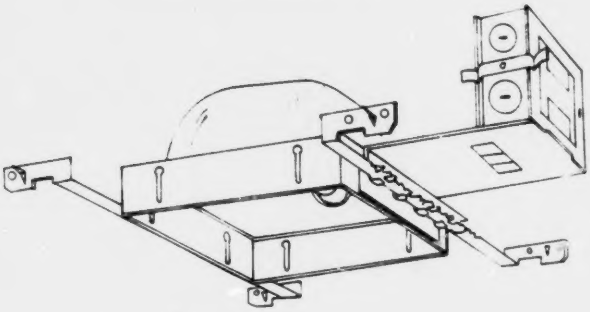


i. ______________________________

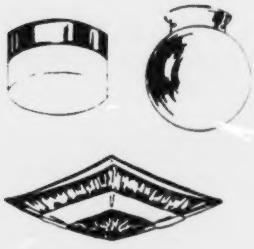
Written Test

4. Match common residential fixture locations on the right with their correct types.

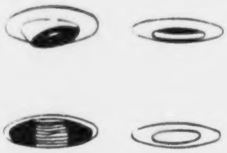
1. Dining room
2. Bedroom or hall
3. Recessed fixtures and trims
4. Bathroom
5. Closet
6. Outdoor entry



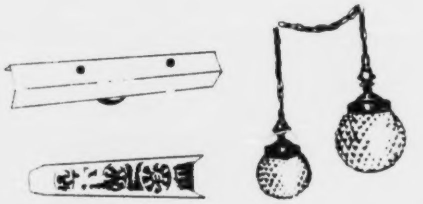
______a.



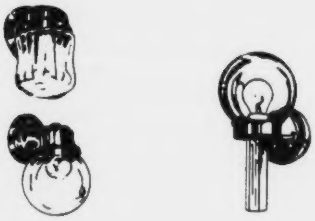
______b.



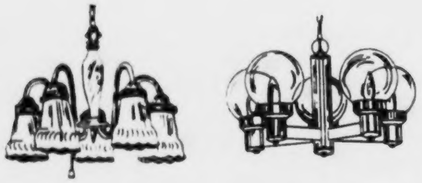
______e.



______c.



______f.



______d.

Written Test

5. Match appliance classifications on the right with their correct descriptions.

______a. A current consuming device which is permanently installed such as water heaters, built-in cook-tops or ovens, and electric furnaces.

______b. A current consuming device not permanently attached but, not ordinarily moved such as clothes dryers, washing machines, and free standing ranges.

______c. A current consuming device which is commonly moved such as blenders, mixers, toasters, and radios.

______d. A branch circuit that supplies only one (1) utilization equipment such as a range, dryer, or washing machine.

______e. Connected to a branch circuit with a pigtail plug inserted into a receptacle such as portable appliances, but may include stationary or fixed-in-place appliances.

1. Cord-and-plug connected
2. Fixed
3. Located on a separate circuit
4. Portable
5. Stationary

6. Distinguish between requirements for appliance disconnect means by placing an "X" for permanently connected appliances next to the correct requirement.

______a. An accessible plug and receptacle shall be permitted to serve as the disconnect means.

______b. The branch circuit breaker shall be permitted to serve as the disconnecting means where readily accessible to the user of the appliance.

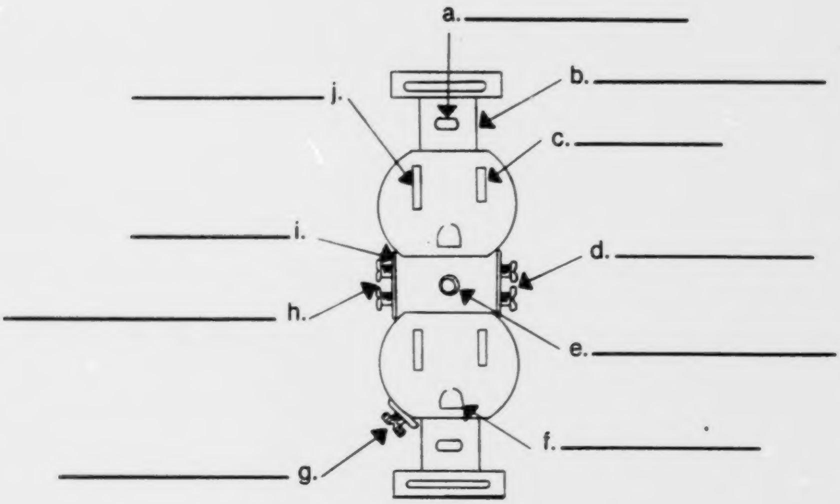
7. State the grounding requirement for appliances.

____

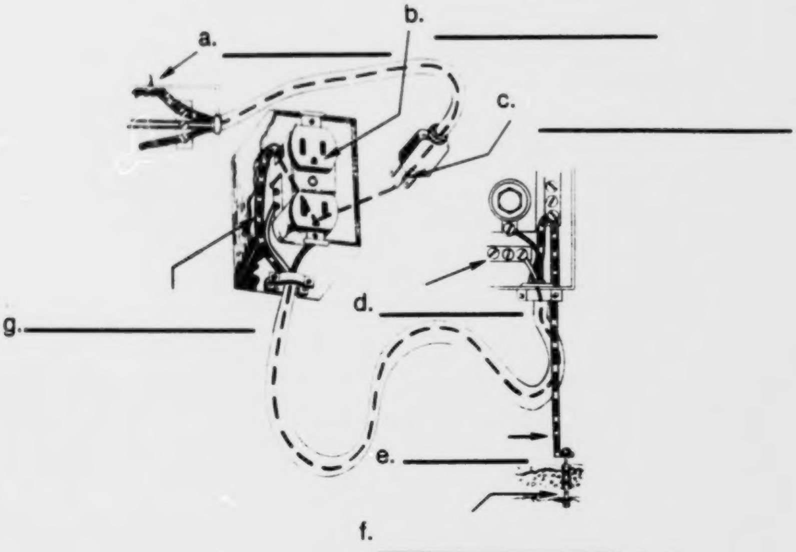
____

Written Test

8. Identify the parts of a duplex grounding type receptacle.


a.
b.
c.
d.
e.
f.
g.
h.
i.
j.

9. Identify the parts of an equipment grounding system.



Written Test

10. Arrange in order the steps for panel trim out by placing a "1" for the first step, a "2" for the second step and so on in the blanks preceding the steps.

______a. Connect ungrounded conductors to their overcurrent protection devices.

______b. Label panel in the form of a directory.

______c. Connect the grounding conductors to their panel location.

______d. Energize the system with temporary power.

______e. Connect grounded conductors to the panel neutral bar.

11. Select true statements concerning troubleshooting procedures by placing an "X" in the blanks preceding the true statements.

______a. Consulting the owner about the operation of a system may help to determine symptoms of a problem causing system.

______b. Locate the problem solving area by turning on the power and waiting for smoke to indicate where the problem is.

______c. Check the conductor to see if it is discolored from overheating or if the insulation is damaged or nicked.

______d. Replace fuse or circuit breaker with a larger size to eliminate breaker trip.

______e. Check devices and fixtures for worn or overheated parts.

______f. Repair or replace cause of problem.

***Permission to duplicate this test is granted.**

Trim Out and Troubleshooting
Unit 4

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Job Sheet 1—Install a Duplex Grounding Type Receptacle Rating ______

Comments: ____

____

Job Sheet 2—Install a Range or Dryer Receptacle Rating ______

Comments: ____

____

Job Sheet 3—Install a Multi-Circuit Split-Wired Duplex Grounding Type Receptacle Rating ______

Comments: ____

____

Job Sheet 4—Wire a Receptacle Fed From a Lighting Outlet Through a Single Pole Switch Rating ______

Comments: ____

____

Job Sheet 5—Connect a Supply Cord to a Free Standing Range Rating ______

Comments: ____

____

Job Sheet 6—Install a Fixed Appliance Equipped With a Pigtail to a Branch Circuit Rating ______

Comments: ____

____

Unit Evaluation Form

Job Sheet 7—Install a Fusible Safety Switch for an Air-Conditioning Condenser Rating ______

Comments: ____________________

____

Job Sheet 8—Troubleshoot an Electrical System Problem Rating ______

Comments: ____________________

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____________________

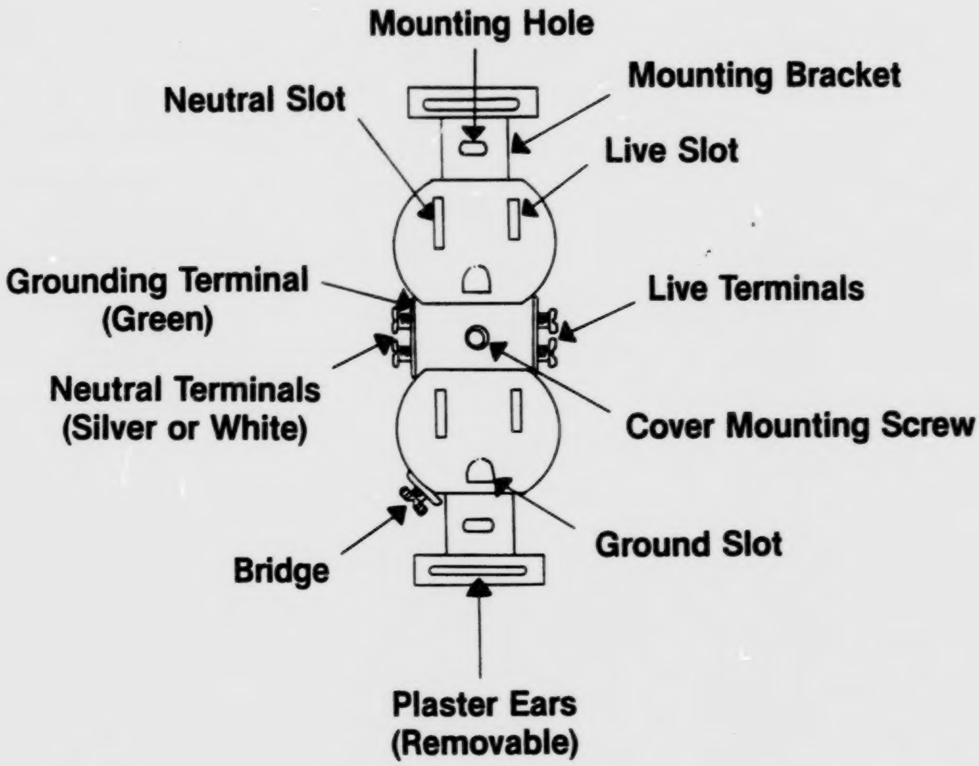
____

Teacher Signature ____________________ Date __________

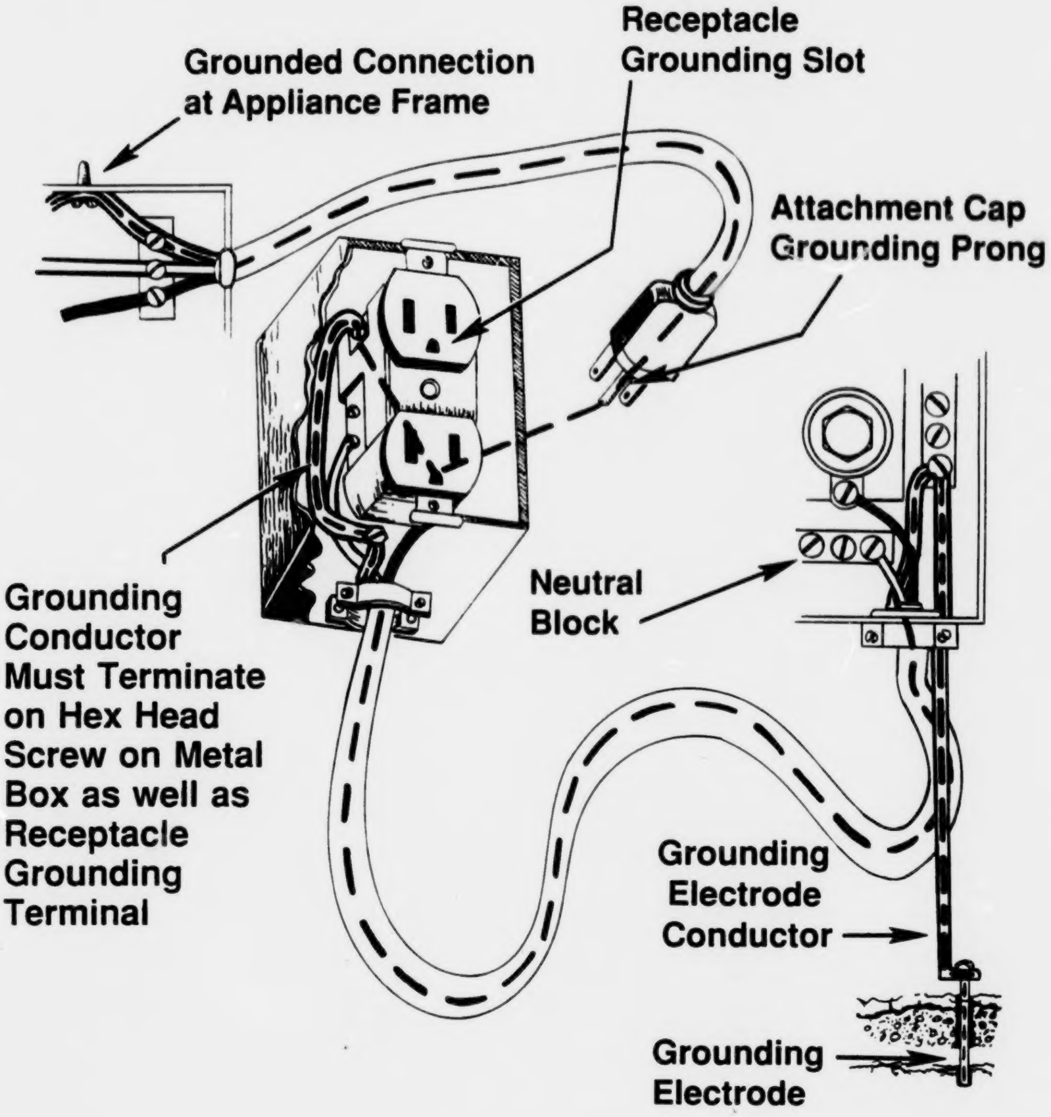
Student Signature ____________________ Date __________

*Permission to duplicate this form is granted.

Parts of a Duplex Grounding Type Receptacle


Mounting Hole
Mounting Bracket
Neutral Slot
Live Slot
Grounding Terminal (Green)
Live Terminals
Neutral Terminals (Silver or White)
Cover Mounting Screw
Ground Slot
Bridge
Plaster Ears (Removable)

Equipment Grounding Circuit


Grounded Connection at Appliance Frame
Receptacle Grounding Slot
Attachment Cap Grounding Prong
Grounding Conductor Must Terminate on Hex Head Screw on Metal Box as well as Receptacle Grounding Terminal
Neutral Block
Grounding Electrode Conductor
Grounding Electrode

Trim Out and Troubleshooting
Unit 4

Information Sheet

1. **Terms and definitions**

   a. **Appliance** — Utilization equipment, generally other than industrial, normally built in standardized sizes or types, which is installed or connected as a unit to perform one or more functions such as clothes washing, air conditioning, food mixing, or deep frying

   b. **Appliance branch circuit** — A 120V branch circuit rated at 1500 VA (20 amps) supplying energy to one or more outlets to which appliances are to be connected

   c. **Cable clamp** — Piece of equipment used to secure cables

   d. **Device** — Unit of an electrical system which is intended to carry but not utilize electrical energy

   e. **Disconnecting means** — A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply

   f. **Duplex grounding receptacle** — A single yoke device with two grounding type receptacles

   g. **Feed through** — The use of a box for splicing or rerouting conductors to get to another location

   h. **Individual branch circuit** — Branch circuit that supplies only one piece of utilization equipment

   i. **Line leg** — Conductor that supplies electrical energy to a switch

   j. **Multiple receptacle** — A single yoke device with two or more receptacles

   k. **Pigtail** — Splicing technique that leaves an accessible conductor for termination at a device, load, or grounding terminal

   l. **Poles** — Current carrying conductors, both grounded and ungrounded, on a receptacle switch or overcurrent device

   m. **Receptacle connecting fin** — Detachable design feature that makes terminals common connections

   n. **Single receptacle** — A single contact device with no other contact device on the same yoke

Information Sheet

o. **Split-wired receptacle** — Receptacle that has had a connecting fin removed for remote control or separate circuit connections

p. **Strap or yoke** — Metal strip containing one or more devices

q. **Switch** — Device used to open or transfer circuit direction

r. **Switch leg** — Conductor that carries electrical energy from the switch to the load

s. **Switch loop** — Conductors between light and switch when supply enters the light

t. **Terminal** — Point of attachment for conductors

u. **Traveler** — Transfer conductors in a switching situation; they are used between 3-ways and 4-ways

v. **Trim out** — Final stage in a residential wiring project; involves devices and plates, connecting and securing equipment, hanging fixture, and testing the system

w. **Troubleshooting** — The systematic diagnosis of a malfunction

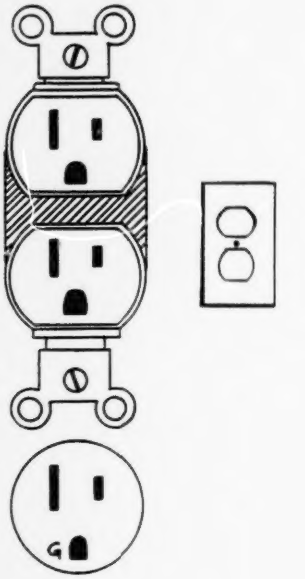
x. **Volt ampere** — Voltage multiplied times amperage

y. **Wires** — Current carrying conductors and grounding conductors

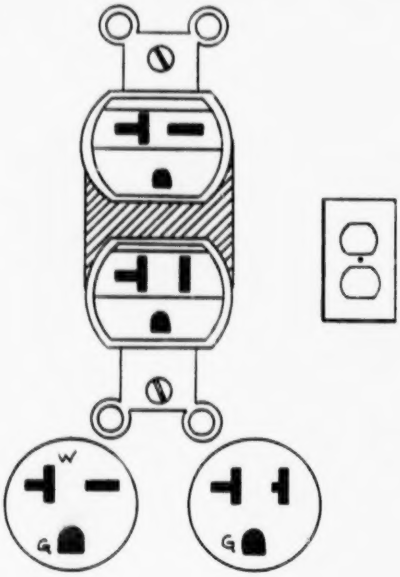
Information Sheet

2. Common residential receptacle types and cover plates

a. Duplex grounding receptacle
125v, 15 amp



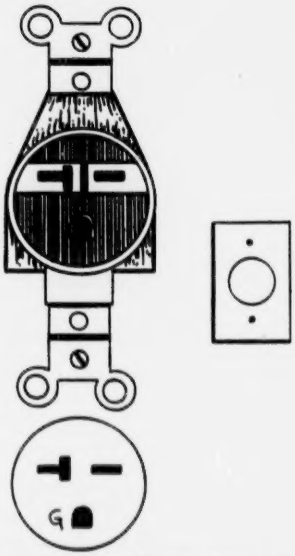
b. Dual voltage receptacle
125/250v, 20 amp



Note: This outlet is configured so as to not allow plug attachment to wrong voltage.

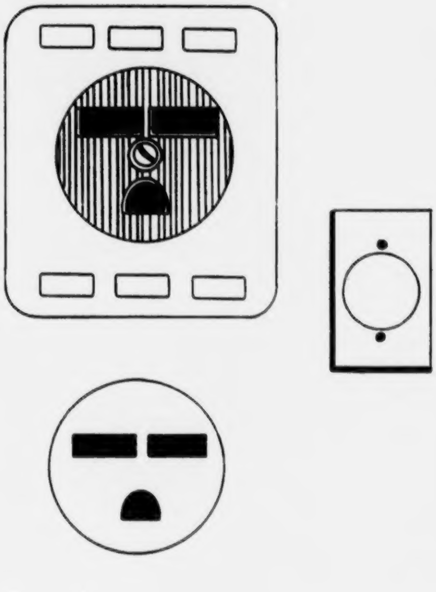
Information Sheet

c. Air conditioner receptacle
250v, 20 amps

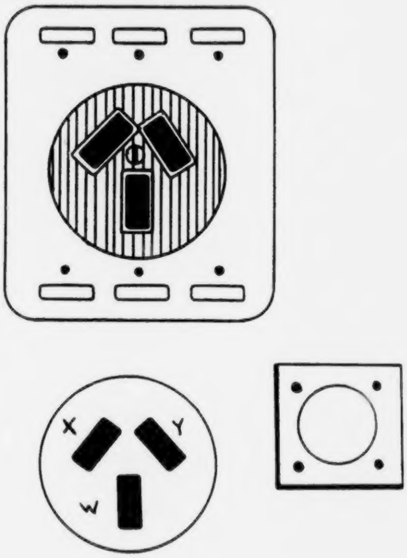


Note: This is often referred to as a "T" blade receptacle.

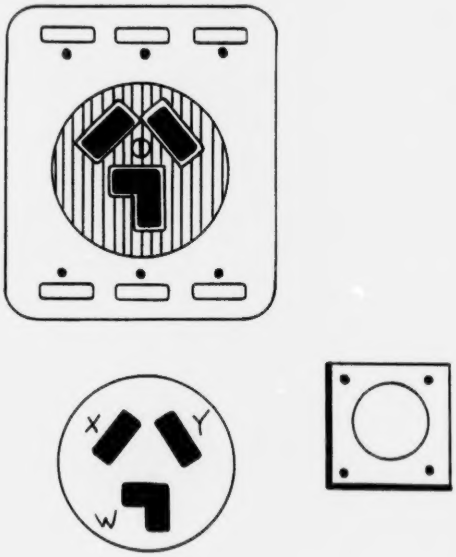
d. Air conditioning receptacle
250 volt, 30 amp



e. Range receptacle
125/250v, 50 amp

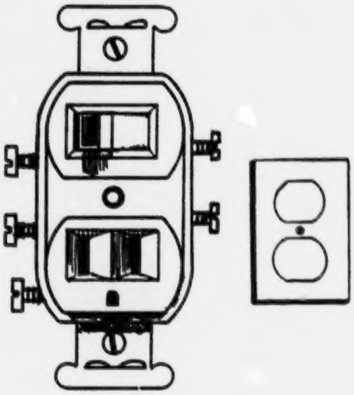


f. Dryer receptacle
125/250 volt, 30 amp

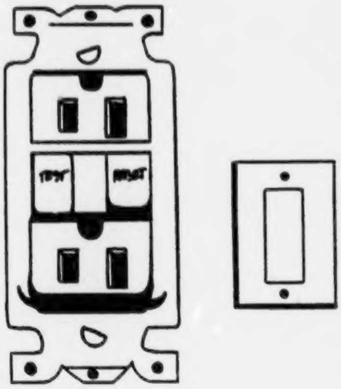


Information Sheet

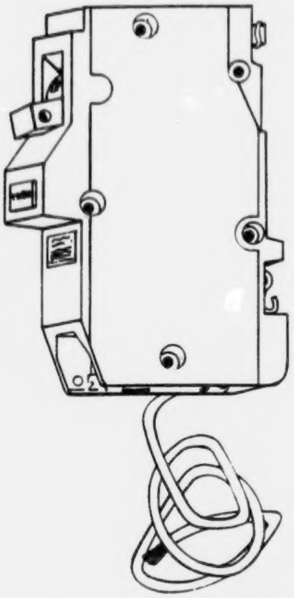
g. Switch and receptacle combination



h. Ground fault receptacle 125v, 15 amp



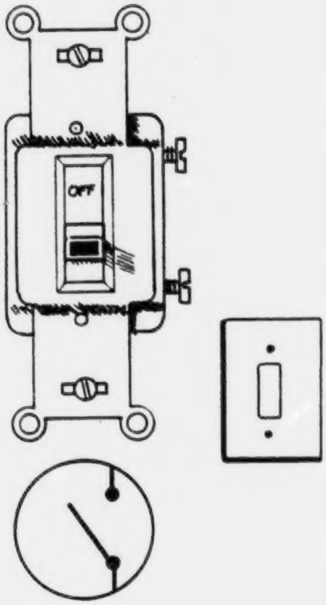
i. Ground fault circuit breaker



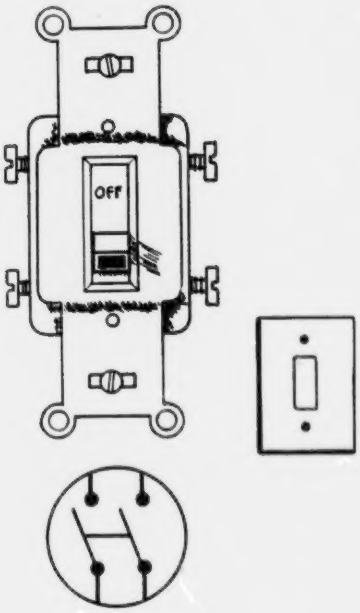
Information Sheet

3. Common residential switch types and cover plates

a. Single pole

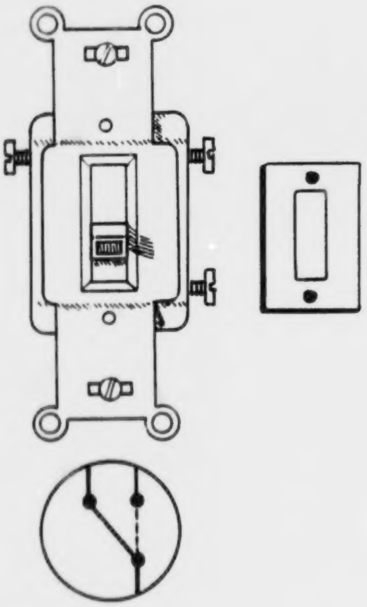


b. Double pole

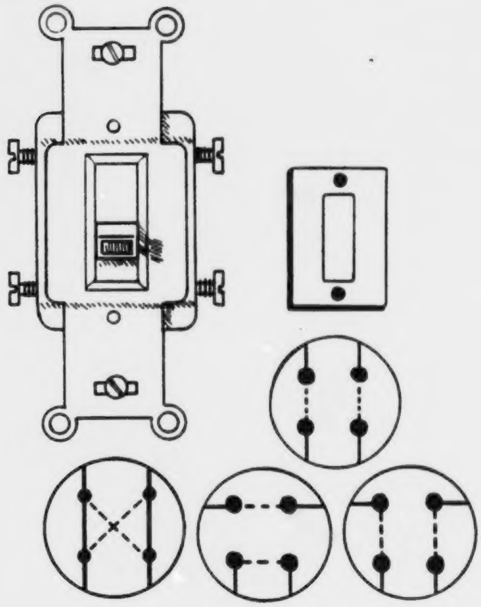


Information Sheet

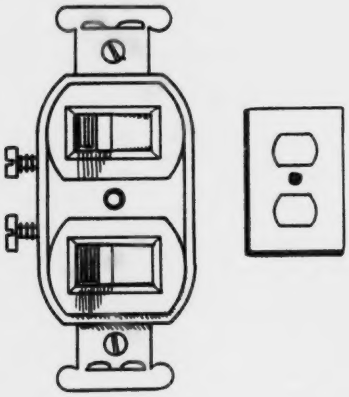
c. Three way



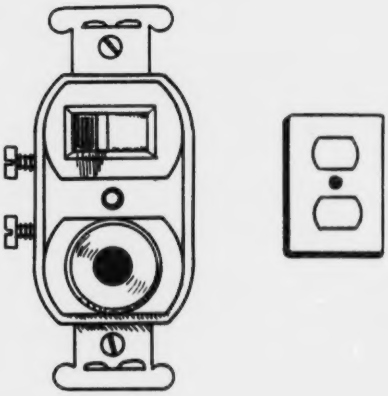
d. Four way



e. Duplex switches

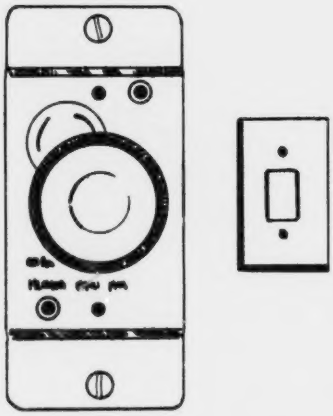


f. Switch and pilot light

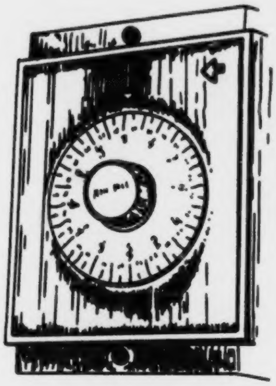


Information Sheet

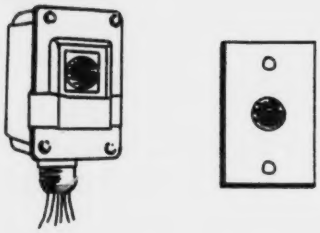
g. Dimmer



h. Timer switch

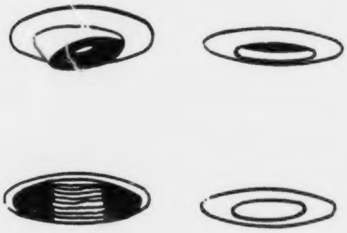


i. Photo cell

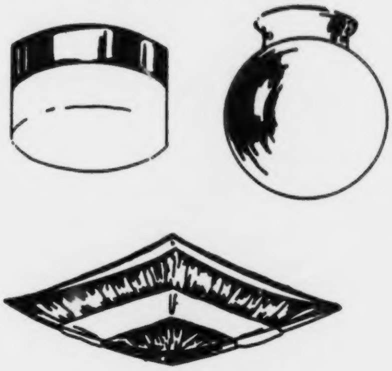


4. **Common residential fixture locations and their types**

a. Recessed fixtures and trims

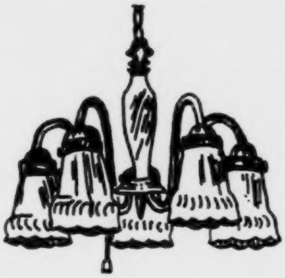


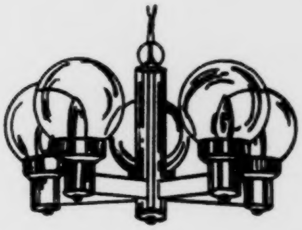
b. Bedroom or hall



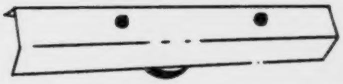
Information Sheet

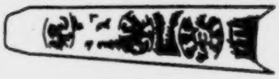
c. Dining room

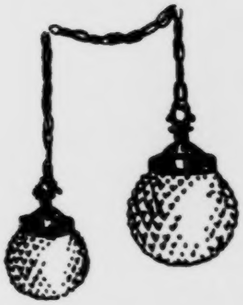




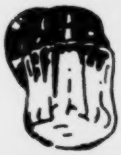
d. Bathroom

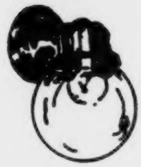


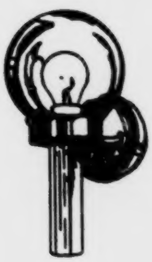




e. Outdoor entry

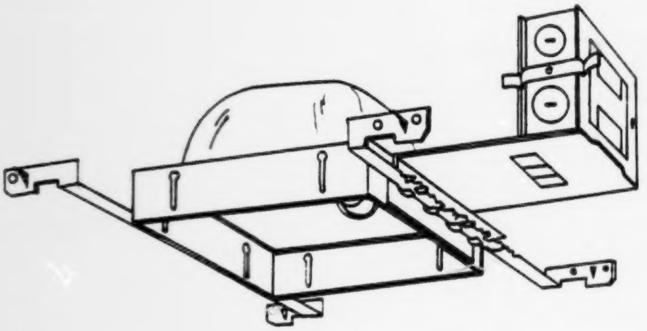






Information Sheet

f. Closet



5. Appliance classifications and their descriptions

Note: *NEC* Art: 422 pertains to regulations for appliances.

a. Fixed — A current consuming device which is permanently installed such as water heaters, built-in cook-tops or ovens, and electric furnaces

b. Stationary — A current consuming device not permanently attached, but not ordinarily moved such as clothes dryers, washing machines, and free standing ranges

c. Portable — A current consuming device which is commonly moved such as blenders, mixers, toasters, and radios

d. Located on a separate circuit — A branch circuit that supplies only one (1) utilization equipment such as a range, dryer, or washing machine

e. Cord and plug connected — Connected to a branch circuit with a pigtail plug inserted into a receptacle such as portable appliances, but may include stationary or fixed-in-place appliances

Note: To comply with *NEC* requirements for cord-and-plug connections for appliances, the receptacles must be readily accessible.

f. Permanently connected — Connected to the branch circuit by solid connection not readily disconnected

Information Sheet

6. **Requirements for appliance disconnect means**

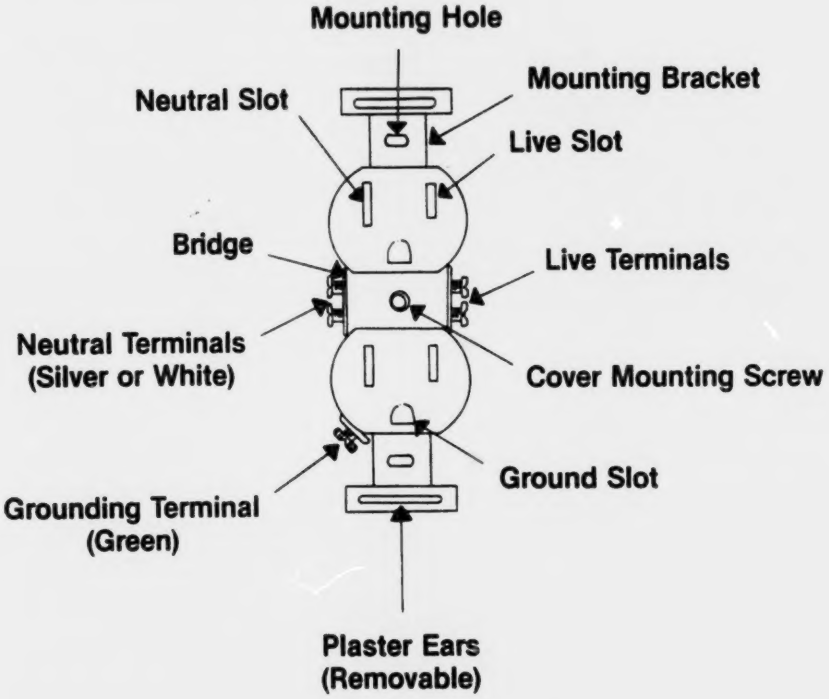
    a. Cord and plug connected appliances — An accessible plug and receptacle shall be permitted to serve as the disconnect means.

    b. Permanently connected — The branch circuit breaker shall be permitted to serve as the disconnecting means where readily accessible to the user of the appliance.

7. **Grounding requirement for appliances** — Appliances with exposed noncurrent carrying metal parts likely to become energized shall be grounded.

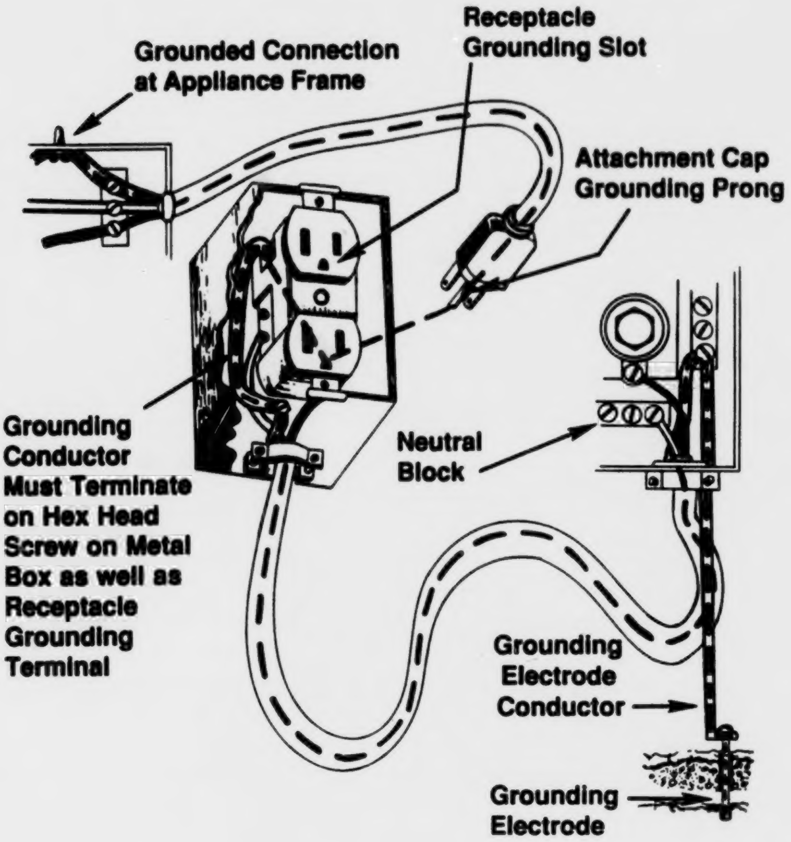
    Note: The exceptions are listed appliances protected by a system of double insulation or its equivalent where distinctively marked. See Sections 250-42, 250-43, 250-45, 250-57, and 250-60 of the *NEC* for specific equipment grounding methods.

8. **Parts of a duplex grounding type receptacle**


Mounting Hole
Mounting Bracket
Neutral Slot
Live Slot
Bridge
Live Terminals
Neutral Terminals
(Silver or White)
Cover Mounting Screw
Ground Slot
Grounding Terminal
(Green)
Plaster Ears
(Removable)

Information Sheet

9. Parts of an equipment grounding system


Receptacle Grounding Slot
Grounded Connection at Appliance Frame
Attachment Cap Grounding Prong
Grounding Conductor Must Terminate on Hex Head Screw on Metal Box as well as Receptacle Grounding Terminal
Neutral Block
Grounding Electrode Conductor
Grounding Electrode

Information Sheet

10. Steps for panel trim out

a. Connect the grounding (bare) conductors (Ref. *NEC* Art. 250 Part K) to their panel location. All grounding conductors attach to the grounding bar or lug (point at which grounding electrode conductor attaches).

Note: With **all** conductor installation and connections inside the panel, neat and orderly forming of conductors is called for. Before conductors are routed inside the panel to a connection point, they should be straightened and preformed in the direction of travel.

b. Connect grounded (neutral) conductors (Ref. *NEC* Art. 250) to the panel neutral bar.

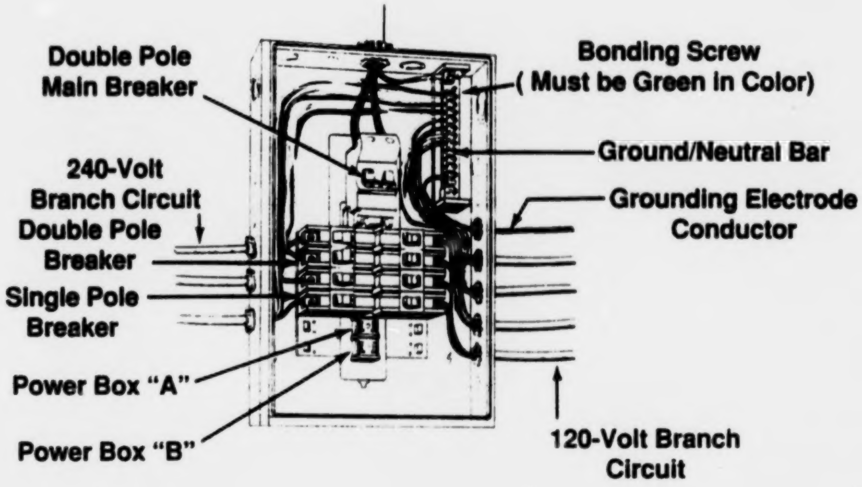
Note: The grounded conductor is normally white but may be another color if identified. In most residential panels the grounding and grounded bar are one in the same. However, for neatness and ease of tracing conductors, these different conductors should be installed in separated positions on the bar.

c. Connect ungrounded (hot) conductors (Ref. *NEC* Art. 230-81) to their overcurrent protection devices (fuse holders or circuit breakers).

Caution: With all multiwire circuits (both "hot" wires share the same neutral) care must be taken to insure that the ungrounded conductors are connected to different bus bar phases. This will prevent neutral overload.

Note: The ungrounded conductors of a multiwire circuit must be simultaneously opened at the panel. This may be secured by connection to a 2-pole circuit breaker or two single-pole circuit breakers with a handle tie. Where fuses are used, a two-pole disconnect switch is required.

Information Sheet


Double Pole
Main Breaker
240-Volt
Branch Circuit
Double Pole
Breaker
Single Pole
Breaker
Power Box "A"
Power Box "B"
Bonding Screw
(Must be Green in Color)
Ground/Neutral Bar
Grounding Electrode
Conductor
120-Volt Branch
Circuit

d. Label panel in the form of a directory. This directory for circuit breaker location should be of a permanent type.

Note: Most panels provide a space for the directory inside panel cover door.

e. Energize the system with temporary power after all other circuit trim out is completed. At this time a complete check out of job should be performed.

Note: Check all circuits for proper operation, correct voltage output, and correct identification through directory.

11. Troubleshooting procedures

a. Determine symptoms of problem causing system. Consult owner about operation of system before, during, and after problem occurred.

Note: A great deal of information can be gained in this questioning—did it flicker, hum, or explode? Was anything unusual going on at the time of problem, lightning, unusual load, too many appliances plugged in, has it happened before?

Information Sheet

b. Inspect the system.

Note: The panel is the place to start since the overcurrent protection device will identify the problem circuit.

- Trace system from panel by
    - — Color of conductor
    - — Number of conductor
    - — Using an ohmmeter

Caution: Always disconnect supply power from circuit to be tested before using ohmmeter. Line voltages will damage meter.

- Check conductor's condition.
    - — Conductor discolored from overheating
    - — Conductor insulation damaged or nicked
    - — Loose conductor connection at devices or splice points
- Check devices or fixtures.
    - — Device worn or overheated
    - — Fixture worn or overheated
    - — Reversed outlet polarity

Note: Lamp wattages shall not exceed manufacturer's recommendations.

c. Locate problem causing area.

- Bad device or fixture
- Broken conductor
- Circuit overload

d. Repair or replace cause of problem

- Install new device or fixture
- Rewire circuit
- Install extra circuit to compensate for overload

Trim Out and Troubleshooting
Unit 4

Job Sheet 1—Install a Duplex Grounding Type Receptacle

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
Device installed securely	______
Device performs correctly when energized	______
Proper polarity maintained	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

Lineworker's pliers
Long nose pliers
Flat blade screwdriver
Pocket knife
Wire strippers
Electrician's hammer
12-2 or 14-2 G NM cable
Device box
Electrical supply
Staples
⅜″ cable connector
Stud wall or work board
Tool pouch

Folding rule with sliding scale or tape
Safety glasses
Drill motor or brace
½″ or larger wood bit

Note: Holes should be large enough to accommodate cables safely.

Extension cord
Duplex grounding type receptacle
Neon test light or voltmeter
GFCI
Polarity tester

B. Procedures

☐ 1. Gather equipment and materials and put on safety glasses.

☐ 2. Mount box.

Note: Remember that your box set-out depends on the thickness of the wall covering to be installed.

Job Sheet 1

☐ 3. Remove a half inch knockout from the panel.

Note: Lineworker's pliers may be needed to finish removing the raised knockout.

☐ 4. Install cable connector.

☐ 5. Bore holes for cable.

Note: Holes should be drilled as close to the center (front to back) of a stud as possible. Holes should be drilled at least 6 inches above or below the box depending on which route is the closest.

Caution: Be sure and hold the drill securely. A loose grip can cause an accident. Be sure and use GFCI protection.

☐ 6. Run cable.

Note: Leave at least 8″ extending past the surface of device box, and enough to reach the top of panel plus half the width.

☐ 7. Staple cable within 12″ of metal boxes, 6″ of nonmetallic boxes.

☐ 8. Secure all cable clamps and connectors.

Caution: Tighten them until the cable will not slip in the box; overtightening can cause an electrical short.

☐ 9. Strip cable insulation at device box and panel.

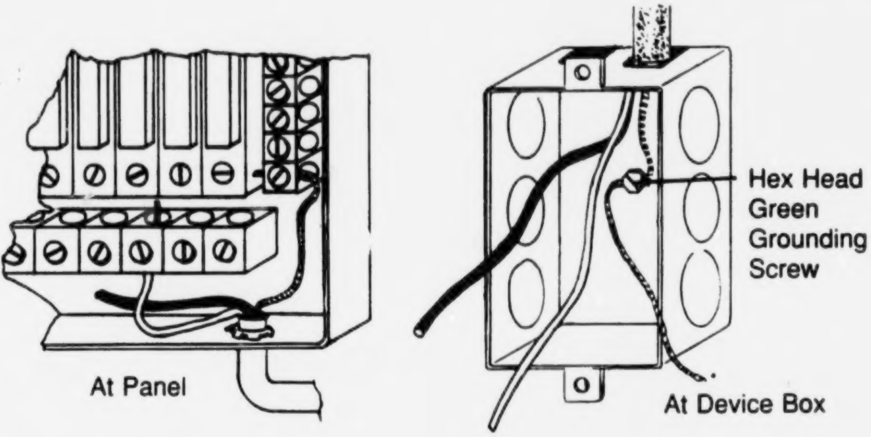
Note: Trim the cable covering to within ¼″ of its point of entry.

Caution: Extreme care should always be used in operations involving a knife; a cut hand can cause pain and lost work time.

Job Sheet 1

☐ 10. Connect equipment grounding conductors and circuit neutral.

Figure 1



At Panel

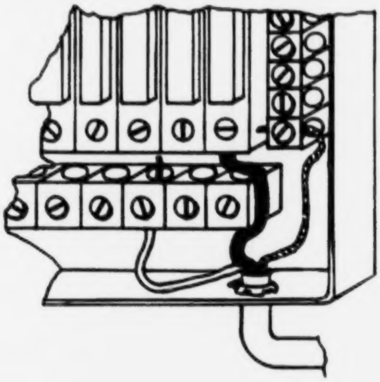
At Device Box

Note: In a residence, all circuit neutrals and equipment grounding conductors would be connected at one time; the procedure is called panel make-up.

☐ 11. Install receptacle.

☐ 12. Connect ungrounded conductor to appropriate overcurrent device.

Figure 2



Note: Be sure the breaker is off or the fuse is out before connecting this conductor. Always be safety conscious.

Job Sheet 1

☐ 13. Turn breaker on or screw fuse in.

Caution: Stand to the side of the panel when turning on the breaker. A short in the circuit could cause molten metal to fly from the panel.

☐ 14. Test receptacle with neon test light, voltmeter, or polarity tester.

☐ 15. Have instructor evaluate this project.

☐ 16. Turn off breaker.

☐ 17. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Trim Out and Troubleshooting
Unit 4

Job Sheet 2—Install a Range or Dryer Receptacle

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	Rating
Device installed securely	______
Device performs correctly when energized	______
Proper polarity maintained	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

Lineworker's pliers
Long nose pliers
Screwdriver
Pocket knife
Wire strippers
Electrician's hammer
10-3 G or 8-3G NM cable
Box

Note: Check *NEC* Art: 370-16 for box requirements.

Electrical supply
Staples
½" or ¾" cable connector
Stud wall or work board
Tool pouch
Folding rule with sliding scale or tape
Safety glasses
Drill motor or brace
½" or larger wood bit
Extension cord
125-250 volt, 30 or 50 amp receptacle
GFCI

B. Procedures

☐ 1. Gather equipment and materials and put on safety glasses.

☐ 2. Mount box.

Note: Remember that your box set-out depends on the thickness of the wall covering to be installed. Be sure your box is rated for your conductors.

Job Sheet 2

☐ 3. Remove a appropriate size knockout from the panel.

Note: Lineworker's pliers may be needed to finish removing the raised knockout.

☐ 4. Install cable connector.

☐ 5. Bore holes for cable.

Note: Holes should be drilled as close to the center (front to back) of a stud as possible. Holes should be drilled at least 6 inches above or below the box depending on which route is the closest.

Caution: Be sure and hold the drill securely. A loose grip can cause an accident. Be sure and use GFCI protection.

☐ 6. Run cable.

Note: Leave at least 8″ extending past the surface of device box, and enough to reach the top of panel plus half the width.

☐ 7. Staple cable within 12″ of metal boxes, 6″ of nonmetallic boxes.

☐ 8. Secure all cable clamps and connectors.

Caution: Tighten them until the cable will not slip in the box; overtightening can cause an electrical short.

☐ 9. Strip cable insulation at device box and panel.

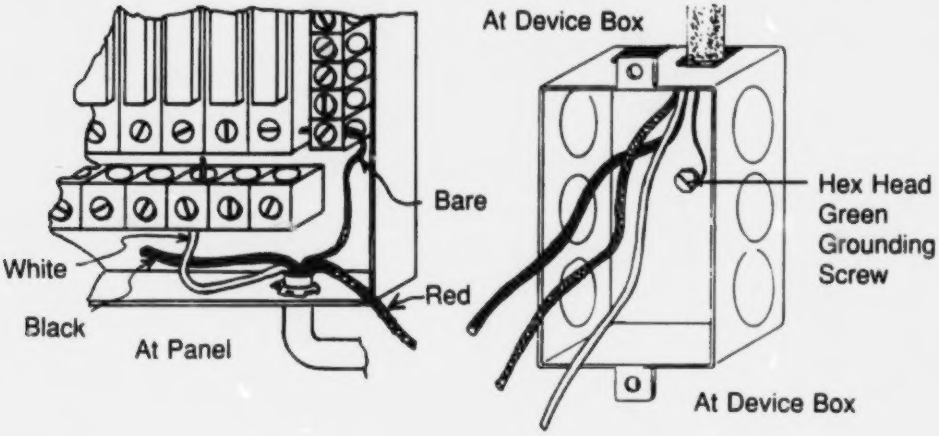
Note: Trim the cable covering to within ¼″ of its point of entry.

Caution: Extreme care should always be used in operations involving a knife; a cut hand can cause pain and lost work time.

Job Sheet 2

☐ 10. Connect neutral and equipment grounding conductors.

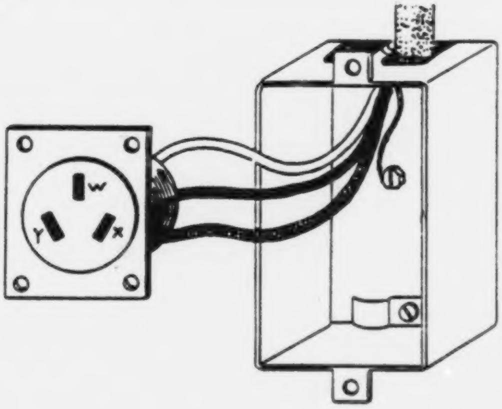
Figure 1


At Device Box
Bare
Hex Head Green Grounding Screw
White
Red
Black
At Panel
At Device Box

Note: You are allowed to use the grounded circuit conductor as the equipment grounding conductor for the frames of ranges and dryers if specific conditions in Article 250 are met.

☐ 11. Install your device.

Figure 2

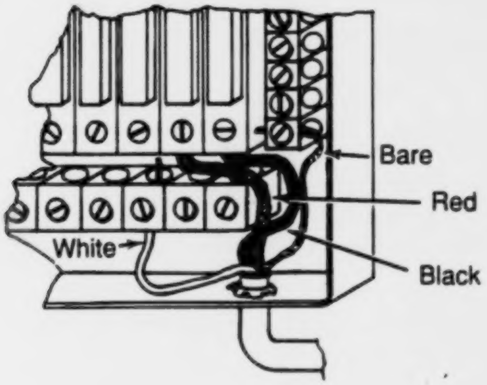


Note: Neutral must be insulated if fed from a subpanel. White conductor goes to terminal labeled "W" or Gr. The red and black connect to other terminals.

Job Sheet 2

☐ 12. Connect ungrounded conductor to appropriate overcurrent device.

Figure 3



Note: Be sure the breaker is off or the fuse is out before connecting this conductor. Always be safety conscious.

☐ 13. Turn breaker on or screw fuse in.

Caution: Stand to the side of the panel when turning on the breaker. A short in the circuit could cause molten metal to fly from the panel.

☐ 14. Test receptacle with neon test light or voltmeter.

☐ 15. Have instructor evaluate this project.

☐ 16. Turn off breaker.

☐ 17. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Trim Out and Troubleshooting
Unit 4

Job Sheet 3—Install a Multi-Circuit Split-Wired Duplex Grounding Type Receptacle

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Device installed securely	______
Device performs correctly when energized	______
Proper polarity maintained	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

- Lineworker's pliers
- Long nose pliers
- Flat blade screwdriver
- Pocket knife
- Wire strippers
- Electrician's hammer
- 12-3 or 14-2G NM cable
- Device box
- Electrical supply
- Staples
- ⅜" cable connector
- Stud wall or work board
- Tool pouch
- Folding rule with sliding scale or tape
- Safety glasses
- Drill motor or brace
- ½" or larger wood bit
- Extension cord
- Circuit tester

B. Procedures

☐ 1. Gather equipment and materials and put on safety glasses.

☐ 2. Mount box.

Note: Remember that your box set-out depends on the thickness of the wall covering to be installed.

Job Sheet 3

☐ 3. Remove a half inch knockout from the panel.

Note: Lineworker's pliers may be needed to finish removing the raised knockout.

☐ 4. Install cable connector.

☐ 5. Bore holes for cable.

Note: Holes should be drilled as close to the center (front to back) of a stud as possible. Holes should be drilled at least 6 inches above or below the box depending on which route is the closest.

Caution: Be sure and hold the drill securely. A loose grip can cause an accident. Be sure and use GFCI protection.

☐ 6. Run cable.

Note: Leave at least 8″ extending past the surface of device box, and enough to reach the top of panel plus half the width.

☐ 7. Staple cable within 12″ of the box.

☐ 8. Secure all cable clamps and connectors.

Caution: Tighten them until the cable will not slip in the box; overtightening can cause an electrical short.

☐ 9. Strip cable insulation at device box and panel.

Caution: Extreme care should always be used in operations involving a knife; a cut hand can cause pain and lost work time.

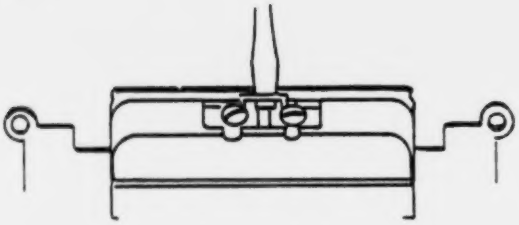
☐ 10. Connect equipment grounding conductors and panel neutral.

Note: In a residence, all circuit neutrals and equipment grounding conductors would be connected at one time; the procedure is called panel make-up.

Job Sheet 3

☐ 11. Break connecting fin from ungrounded side of receptacle.

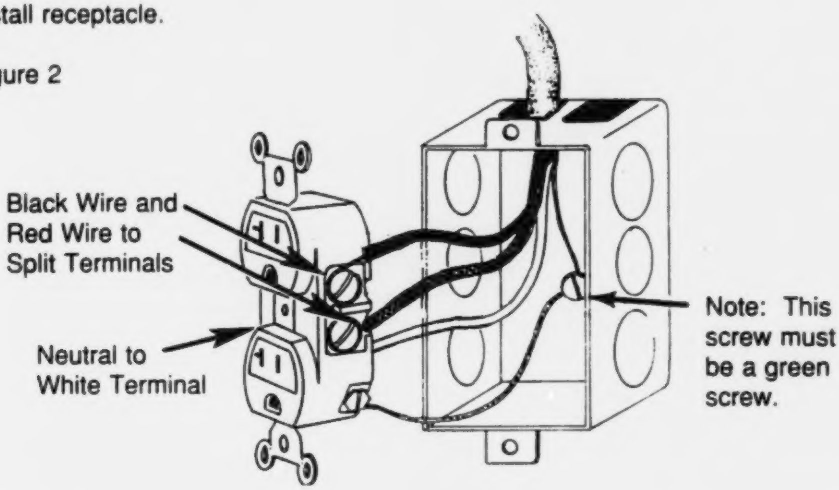
Figure 1



Note: Repeated bending motions will probably be needed to remove the connecting fin.

☐ 12. Install receptacle.

Figure 2

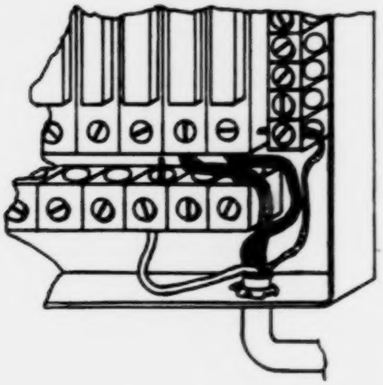

Black Wire and Red Wire to Split Terminals
Neutral to White Terminal
Note: This screw must be a green screw.

Note: A common neutral is allowed on multi-wire branch circuits where there is dual voltage potential difference between ungrounded conductors.

Job Sheet 3

☐ 13. Connect ungrounded conductor to appropriate overcurrent device. Overcurrent device must be a double pole breaker or two single-pole breakers with atic handle between them.

Figure 3



Note: Be sure the breaker is off or the fuse is out before connecting this conductor. Always be safety conscious.

☐ 14. Turn breaker on or screw fuse in.

Caution: Stand to the side of the panel when turning on the breaker. A short in the circuit could cause molten metal to fly from the panel.

☐ 15. Test receptacle with circuit tester or voltmeter.

☐ 16. Have instructor evaluate this project.

☐ 17. Turn off breaker.

☐ 18. Clean work area and put away all equipment and materials.

Evaluator's comments: ______________________________

____

____

Trim Out and Troubleshooting
Unit 4

Job Sheet 4—Wire a Receptacle Fed From a Lighting Outlet Through a Single Pole Switch

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Devices installed securely	______
Fixture installed securely	______
Receptacle energized with breaker turn on	______
Correct polarity maintained	______
Fixture controlled by switch on/off	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

12-2-G or 14-2-G NM cable
12-3-G or 14-3-G NM cable
Two device boxes
Octagon box and bar hanger
Light socket
120 volt bulb
Staples
Single pole switch
Duplex grounding type receptacle
Stud wall or work board
120v supply

Note: The overcurrent protection on this supply should not exceed the conductors *NEC* ampacity rating.

Wire connectors
Four 16 penny nails or other fasteners as needed to secure the boxes
Electrician's hammer
Plain tip screwdriver
Lineworker's pliers
Long nose pliers
Pocket knife
Wire strippers
Tool pouch
Drill motor or brace
½" or larger wood bit
Extension cord
Safety glasses
GFCI
Polarity tester

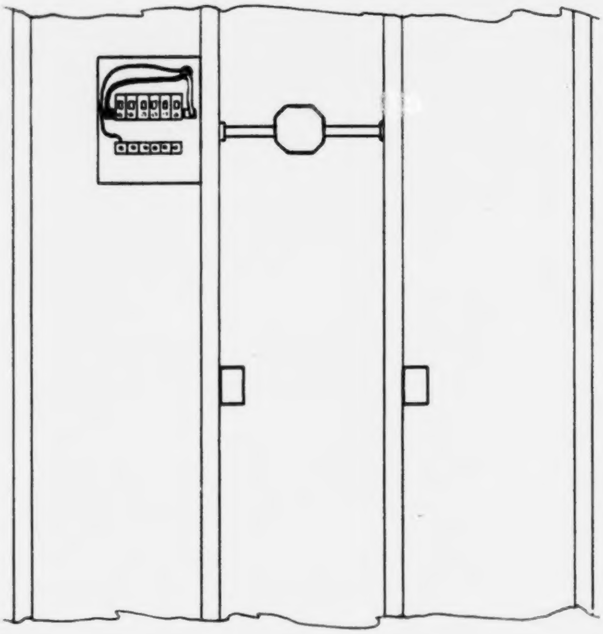
Job Sheet 4

B. Procedures

☐ 1. Gather equipment and materials and put on safety glasses.

☐ 2. Mount boxes.

Figure 1



☐ 3. Remove a half-inch knockout from the panel.

☐ 4. Install cable connector.

☐ 5. Bore holes for cable.

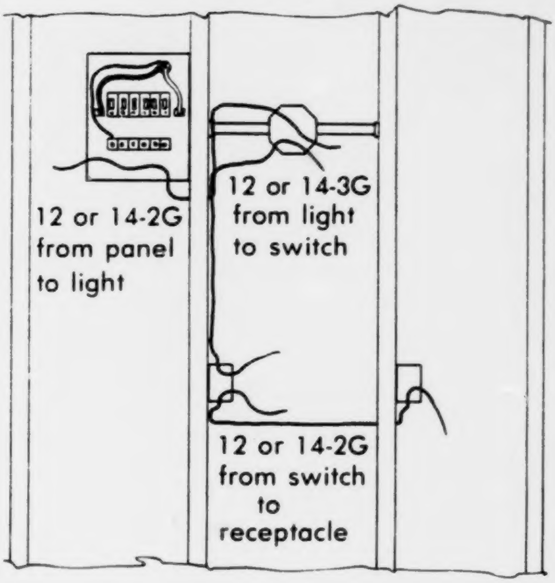
Note: Holes should be drilled as close to the center (front to back) of a stud as possible. Holes should be drilled at least 6 inches above or below the box depending on which route is the closest.

Caution: Be sure and use a GFCI protection.

Job Sheet 4

☐ 6. Run cable between boxes and to panel.

Figure 2


12 or 14-2G from panel to light
12 or 14-3G from light to switch
12 or 14-2G from switch to receptacle

Note: Leave at least 8″ extending past the surface of device box, and enough to reach the top of panel plus half the width.

☐ 7. Staple cable within 12″ of metal boxes, 6″ of nonmetallic boxes.

☐ 8. Secure all cable clamps and connectors.

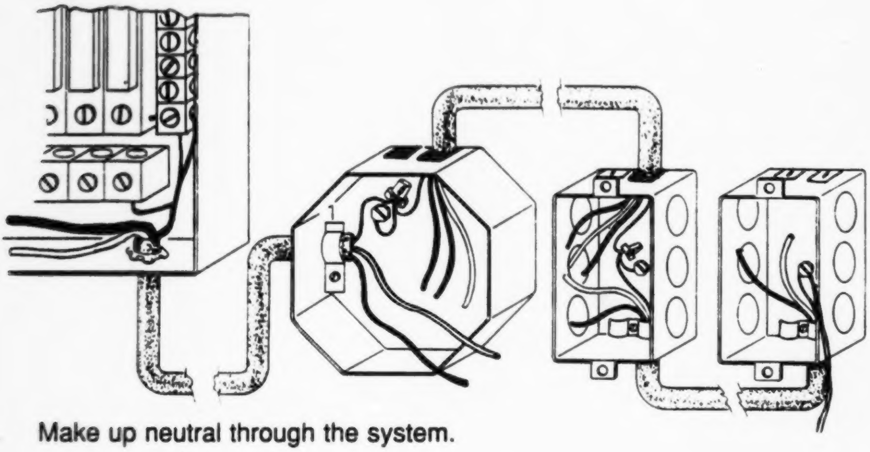
Caution: Tighten them until the cable will not slip in the box; overtightening can cause an electrical short.

☐ 9. Strip cable insulation at device box and panel.

Job Sheet 4

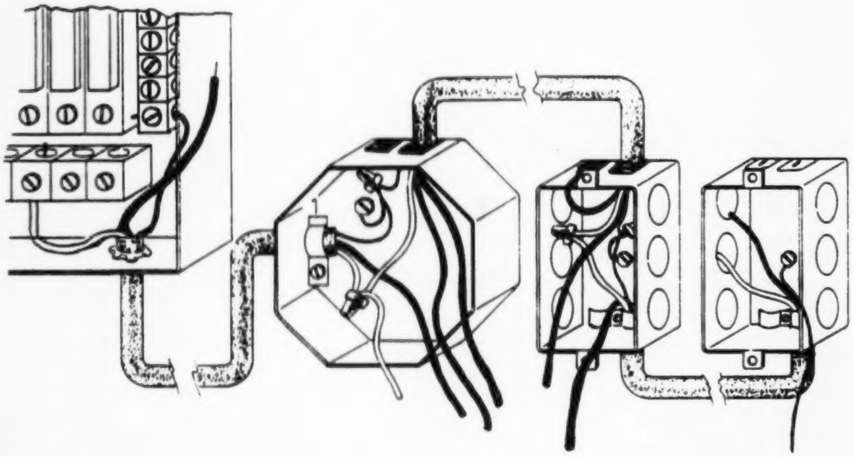
☐ 10. Connect equipment grounding conductors.

Figure 3



☐ 11. Make up neutral through the system.

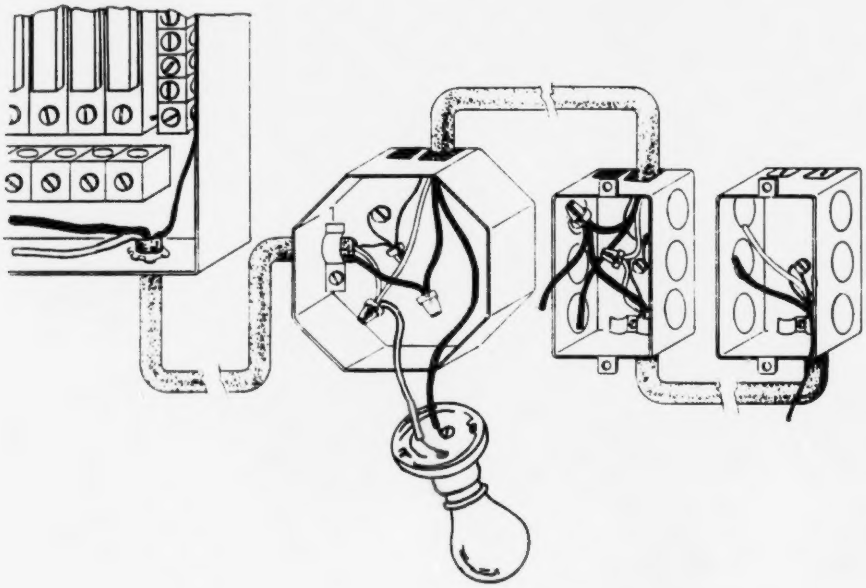
Figure 4



Job Sheet 4

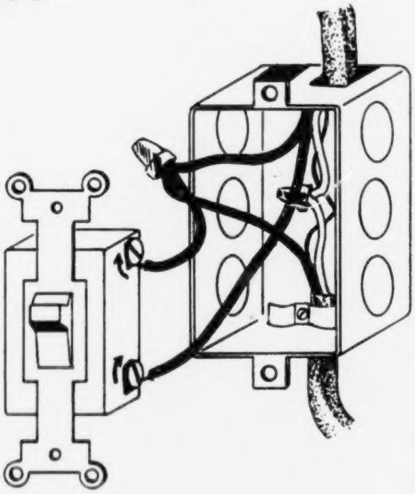
☐ 12. Make up switch, return, feed through conductors, and install light fixture.

Figure 5



☐ 13. Install switch.

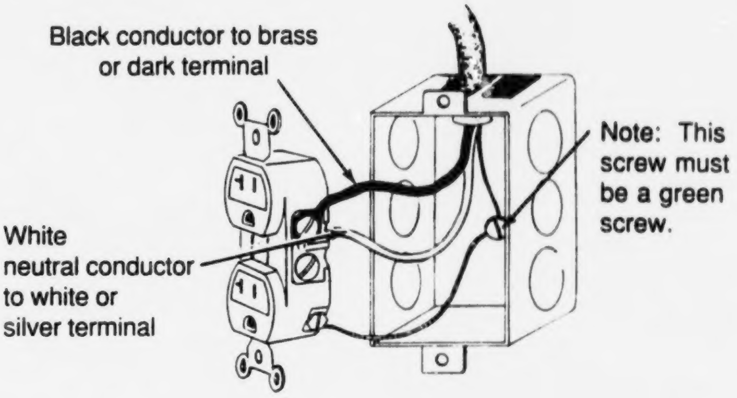
Figure 6



Job Sheet 4

☐ 14. Install receptacle.

Figure 7


Black conductor to brass or dark terminal
Note: This screw must be a green screw.
White neutral conductor to white or silver terminal

☐ 15. Connect return leg and neutral to light socket.

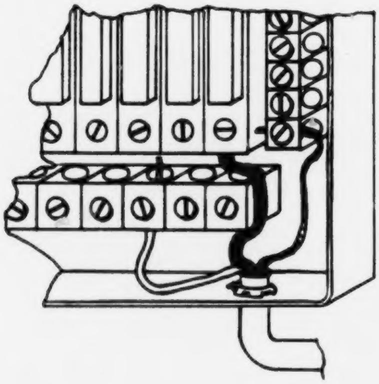
☐ 16. Connect equipment grounding conductor.

☐ 17. Connect grounded conductor first.

Note: Be sure the breaker is off or the fuse is screwed out before connecting this conductor. Always be safety conscious.

☐ 18. Connect ungrounded conductor.

Figure 8



Job Sheet 4

☐ 19. Turn on breaker or screw in fuse.

☐ 20. Turn on switch.

Note: Light should burn.

☐ 21. Test receptacle with test light, V.O.M., or polarity tester.

☐ 22. Have your instructor evaluate this project.

☐ 23. Turn off breaker.

☐ 24. Clean work area and put away all equipment and materials.

Evaluator's comments: ______________________________

____

____

Trim Out and Troubleshooting
Unit 4

Job Sheet 5—Connect a Supply Cord to a Free Standing Range

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
Appliance operates properly when energized	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

Screwdriver
Appropriate appliance cord

Note: Cord must be acceptable to the *NEC* and local code enforcing agent.

Free standing range
Nut driver set
Safety glasses

B. Procedure

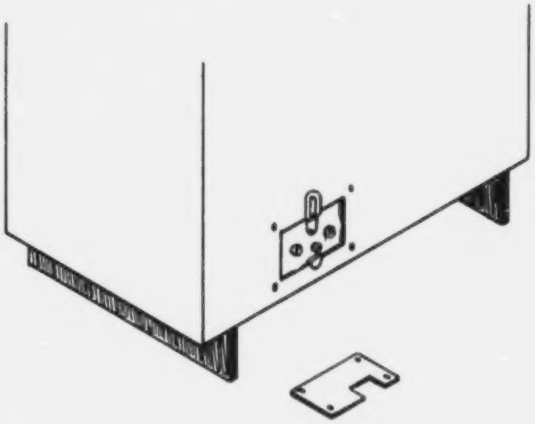
☐ 1. Gather equipment and materials and put on safety glasses.

☐ 2. Position range in best possible working position.

Job Sheet 5

☐ 3. Remove appliance terminal cover plate.

Figure 1



☐ 4. Install cord securing equipment.

Note: Most range cord sets have a clamp included with the cord.

☐ 5. Connect ungrounded conductors to appropriate terminals.

☐ 6. Connect equipment grounding conductor.

Note: The frame of the range may be grounded to the grounded circuit conductor, providing it is not smaller than a No. 10 copper.

☐ 7. Check cord conductors.

Note: Conductors should be arranged so that a pull on the cord will put tension on the cord connector, not the appliance terminals.

☐ 8. Replace cover plate.

☐ 9. Plug in appliance.

☐ 10. Check appliance for correct operation.

Note: Be sure and remove all tape and packing from the oven before testing. Level the oven before your leave.

☐ 11. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Trim Out and Troubleshooting
Unit 4

Job Sheet 6—Install a Fixed Appliance Equipped With a Pigtail to a Branch Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	Rating
Appliance operates properly when energized	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

Box and cover

Note: Be sure box has a capacity rating to accommodate the conductors being used.

Fixed appliance with pigtail

Note: Pigtail should consist of approved flexible cord or conduit with proper sized conductors for the appliance being connected.

Connectors

Note: The pigtail may have a connector already on it. A cable connector will probably be needed if not internal with the box.

Two #12 × 1" MTS screws
Wire connectors

Note: Wire nuts, crimp sleeves, and tape or any other code approved method are acceptable.

Screwdriver
Pocket knife
Wire strippers
Safety glasses

Job Sheet 6

B. Procedure

Note: Be sure that the branch circuit you are working around is not energized.

☐ 1. Gather equipment and materials and put on safety glasses.

☐ 2. Determine box location.

Note: Be sure and place the box within six feet of the appliance to be connected.

☐ 3. Mount the box.

Note: Be sure the box will not interfere with the installation of the appliance.

☐ 4. Install branch circuit conductors in the box.

☐ 5. Position the appliance so the pigtail will reach the box.

☐ 6. Connect appliance pigtail to box.

Figure 1

Connecting Counter Top Cooking Unit

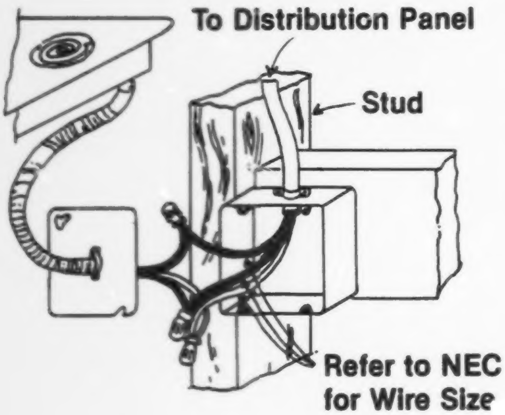
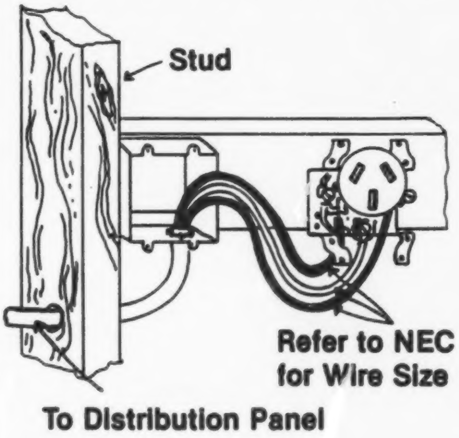

To Distribution Panel
Stud
Refer to NEC for Wire Size

Figure 2

Connecting Range and Receptacle


Stud
Refer to NEC for Wire Size
To Distribution Panel

Note: If a metal box is used, an equipment ground is required.

☐ 7. Splice appliance supply conductors to branch circuit conductors.

Note: Be sure and make mechanically secure connections.

☐ 8. Install cover plate on box.

Job Sheet 6

☐ 9. Position appliance for securing.

☐ 10. Activate circuit and check appliance.

☐ 11. Rest appliance in its correct position.

Note: Make sure the pigtail is not in a bind.

☐ 12. Secure and level appliance.

☐ 13. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Trim Out and Troubleshooting
Unit 4

Job Sheet 7—Install a Fusible Safety Switch for an Air-Conditioning Condenser

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Disconnect switch mounted correctly	______
Correct voltage available when circuit energized	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

Pouch tools
Raintight fusible safety switch

Note: Refer to *NEC* Art: 430-110.

Connecting equipment for switch

Note: If this is a new house, a rigid metal conduit or EMT nipple should have been installed during the rough-in and should be extending just beyond the surface of the exterior wall.

Fasteners

Note: Anchors and screws will be required for brick or concrete; wood screws will work on wood siding.

Safety glasses
Pencil
Drill motor and appropriate bit
GFCI

Job Sheet 7

B. Procedure

☐ 1. Gather equipment and material and put on safety glasses.

☐ 2. Mark mounting holes for switch.

Note: Remember the switch must be within sight of the unit and readily accessible. Check the applicable code requirements of *NEC* Art: 440-14 and 110-16.

☐ 3. Connect supply raceway or connector to switch.

Note: The following items are three possible rough-in techniques that could be encountered.

- Cable only visible
    - — Situate cable so not in a bind.
    - — Install a seal tight clamp on the cable.
    - — Connect cable to box.

    Note: You may have to chisel around the cable to allow the connector freedom.

- Rigid conduit with threads
    - — Adjust conduit so appropriate amount extends inside the box.

    Note: There should be enough to install a locknut and a bushing.

    - — Install back up locknut.
    - — Install interior locknut and bushing.

- EMT
    - — Put a raintight connector on EMT.
    - — Adjust conduit so switch fits flat against wall.

☐ 4. Secure switch to the wall.

Note: If holes need to be drilled be sure and use GFCI.

☐ 5. Connect grounded conductors.

Note: If a bar or lug is not supplied you can mount on a lug.

Job Sheet 7

☐ 6. Connect ungrounded conductors.

☐ 7. Activate circuit.

☐ 8. Test across and between line lugs.

☐ 9. Close cover.

☐ 10. Clean work area and put away all equipment and materials.

Evaluator's comments: ______________________________

____

____

Trim Out and Troubleshooting
Unit 4

Job Sheet 8—Troubleshoot an Electrical System Problem

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
Disconnect switch mounted correctly	______
Correct voltage available when circuit energized	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Equipment and materials

Pouch tools
Volt-ohm-ammeter
Safety glasses
Auxiliary lighting

B. Procedure

☐ 1. Familiarize yourself with the system.

- Locate supply panel and any subpanels or disconnects.
- Know system voltage and other data.
- Trace circuits out mentally and physically if possible.

☐ 2. Ask owner about the problem.

- Ask about performance prior to the problem.
- Ask about problem symptoms.
- Inquire about maintenance procedures.
- Ask if this problems has happened before.

Job Sheet 8

☐ 3. Inspect the system.

- Look for discolorations on equipment.
- Smell for unusual odors.
- Look for frayed cords.
- Watch for improperly installed or connected appliances.

☐ 4. Operate the system if safely possible.

- Turn off switches.
- Unplug appliances.
- Check voltages.

☐ 5. List possible problem causes.

Note: Use your knowledge of the system plus information received from the troubleshooting techniques used to this point.

☐ 6. Formulate a conclusion.

- Review list of probable causes.
- Select cause.

☐ 7. Test conclusion.

Note: Test the conclusion you have reached before repairing the system if possible.

☐ 8. Clean work area and put away all equipment and materials.

Evaluator's comments: ______________________________

____

____

Load Center Changes
Unit 5

Objective Sheet

Unit Objective

After completing this unit, the student should be able to change out existing load centers or add supplemental load centers to existing panels. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to load center changes with their correct definitions.
2. Describe the three basic types of load centers.
3. Match reasons for load center changes with their correct causes.
4. List possible ways to increase service size on an existing dwelling.
5. Select true statements concerning procedure for changing existing service.
6. Replace an existing interior flush mount load center. (Job Sheet 1)
7. Install a rainproof load center to supplement an existing interior load center. (Job Sheet 2)

Load Center Changes
Unit 5

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss and demonstrate the procedures outlined in the job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Record job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Contact a local utility company representative and invite him/her to visit class to discuss requirements for electricians disconnecting or reconnecting service drop conductors. Have students take notes, then provide an opportunity for students to ask questions concerning topic. Skill areas: **listening, writing, and oral communication**.
2. Invite a local code enforcement representative to class to discuss local regulations regarding inspection requirements for service change outs. Have students take notes, then provide an opportunity for students to ask questions concerning topic. Skill areas: **listening, writing, and oral communication**.
3. Construct trainer boards to simulate existing service riser and panel installations to be changed out in the job sheets.
4. Contact a local contractor to arrange a job site visit for class to observe a live work change out. Have students write a brief summary of what they observed and note any questions they have concerning this procedure. Skill area: **writing**.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

Resources Used in Developing This Unit

1. *1993 National Electrical Code®*. Quincy, MA: National Fire Protection Association, 1992.
2. Taylor, Mark. *Residential Wiring*. Revised. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

Suggested Supplemental Resources

1. Holzman, Harvey W. *Modern Residential Wiring*. South Holland, IL: Goodheart-Willcox Co., Inc., 1991.
2. Mullin, Ray C. *Electrical Wiring: Residential*, 11th ed. Albany, NY: Delmar Publishers Inc., 1993.
3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code®*. Albany, NY: Delmar Publishers Inc., 1993.

Suggested Activities

Instructions for Evaluating Student Performance

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Load Center Changes
Unit 5

Answers to Written Test

1. a. 1
   b. 4
   c. 2
   d. 6
   e. 3
   f. 5

2. a. Flush interior — Mounted behind wall covering with opening flush with the wall covering
   b. Surface interior — Mounted in the surface of the wall covering inside the dwelling
   c. Surface exterior — Mounted on the surface of the wall covering outside the dwelling

3. a. 1
   b. 1
   c. 2
   d. 2
   e. 1
   f. 2

4. a. Install larger service entrance conductors in existing raceway and increase load center main breaker size accordingly.
   b. Increase service conductor size and set a new exterior load center with main breaker sized to supply new and existing loads.
   c. Make a complete service change out.

5. a, b, c, d

Load Center Changes
Unit 5

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

   ______a. Refrigeration equipment that sits outside a residential dwelling and is used to remove heat from refrigerant; usually contains a hermetically sealed compressor

   ______b. A factory assembled metal cabinet consisting of fuses or circuit breakers for overcurrent protection of electrical wiring

   ______c. Amperage at which equipment is designed to operate

   ______d. The interior and exterior wiring including power, lighting, control and signal circuits together with associated hardware, fittings, and wiring devices

   ______e. Equipment necessary to keep patients alive

   ______f. Period during which no current is available to circuits in a residential dwelling

   1. Air conditioning condenser
   2. Full load amps (F.L.A.)
   3. Life sustaining medical equipment
   4. Load center
   5. Outage
   6. Premises wiring

2. Describe the three basic types of load centers.

   a. Flush interior — ______________________________

   ____

   b. Surface interior — ______________________________

   ____

   c. Surface exterior — ______________________________

   ____

Written Test

3. Match reasons for load center changes on the right with their correct causes of increased load.

______a. Addition of window air conditioner

______b. Increased kitchen loads (microwave and disposer)

______c. Utility room addition

______d. Remodel kitchen

______e. Install electric clothes dryer

______f. New deck with hot tub

1. Load center changes with no structural change
2. Load center changes with structural change

4. List three possible ways to increase service size on an existing dwelling.

a. ____

b. ____

c. ____

5. Select true statements concerning procedures for changing an existing service by placing an "X" in the blanks preceding the true statements.

______a. Calculate new service size needed.

______b. Estimate materials and labor needed.

______c. Consult with customer about best possible time to do the work.

______d. Contact utility company and local code enforcement authority about the project.

______e. Start load center and service change out on occupied dwelling and complete at your convenience.

***Permission to duplicate this test is granted.**

Load Center Changes
Unit 5

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Job Sheet 1—Replace an Existing Interior Flush Mount Load Center Rating _____

Comments: ____

____

Job Sheet 2—Install a Rainproof Load Center to Supplement an Existing Interior Load Center Rating _____

Comments: ____

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

*Permission to duplicate this form is granted.

Load Center Changes
Unit 5

Information Sheet

1. **Terms and definitions**

   a. **Air-conditioning condenser** — Refrigeration equipment that sits outside a residential dwelling and is used to remove heat from refrigerant; usually contains a hermetically sealed compressor

   b. **Full load amps** (F.L.A.) — Amperage at which equipment is designed to operate

   Note: This information can usually be found on the equipment name-plate.

   c. **Life sustaining medical equipment** — Equipment necessary to keep patients alive

   Note: This could be an iron lung, kidney machine, or any other machine used to replace or sustain a bodily function.

   d. **Load center** — A factory assembled metal cabinet consisting of fuses or circuit breakers for overcurrent protection of electrical wiring

   e. **Outage** — Period during which no current is available to circuits in a residential dwelling

   f. **Premises wiring** — The interior and exterior wiring including power, lighting, control and signal circuits together with associated hardware, fittings, and wiring devices

2. **Basic types of load center**

   a. Flush interior — Mounted behind wall covering with opening flush with the wall covering

   b. Surface interior — Mounted in the surface of the wall covering inside the dwelling

   c. Surface exterior — Mounted on the surface of the wall covering outside the dwelling

Information Sheet

3. **Reasons for load center changes**

   a. Load center changes with no structural changes

      - Addition of window air conditioner unit or central air conditioning unit
      - Addition of increased laundry load (electric clothes dryer)
      - Addition of increased kitchen loads (microwave oven garbage disposal, trash compactor, etc.)
      - Change out old, worn out load center

   b. Load center changes with structural changes

      - Room additions to existing dwellings (extra bedroom, utility room, den, or family center)
      - Remodel existing dwelling (new kitchen, wall removal, or refurbish interior walls)
      - Addition of a deck area for swimming pool or hot tub

      Note: Any change made to existing wiring will require that the premises wiring involved be brought up to existing code standards.

4. **Possible ways to increase existing service size**

   a. Install larger service entrance conductors in existing raceway and increase load center main breaker size accordingly.

      Note: This method will only work if the raceway is large enough, the load center bus is rated for increased size, and the main breaker is interchangeable and the panel has sufficient space for additional circuit breakers.

   b. Increase service conductor size and set a new exterior load center with main breaker sized to supply new and existing loads.

      Note: Raceway must be changed if it is not rated for increased conductor size. A separate breaker must be installed in the new exterior panel to feed the old panel as a subpanel.

   c. Make a complete service change out.

      Note: This is the most extensive change and must include all new equipment (service raceway and conductor and load center).

Information Sheet

5. Procedures for changing an existing service

Note: Always check with local utility company and code enforcement authority before starting.

a. Calculate new service size needed.

Note: It is possible to use Unit 1, Blueprint Reading and Load Calculations, for sizing the new service.

b. Estimate materials and labor needed.

Note: This involves exact calculation of material cost (plus mark-up) and estimated labor cost to install the materials. Do not forget to include in estimate any permit or inspection fees for local code enforcement compliance.

c. Consult with customer about best possible time to do the work.

Note: Be sure no life sustaining medical equipment is involved in the outage. In extreme summer heat, this may include air conditioning units.

d. Contact utility company and local code enforcement authority about the project.

Note: The utility company may require inspection by the local code enforcement officer before reconnecting the service conductors to the service drop conductors. They may even need to increase their service drop conductors size.

e. Start and complete load center and service change out.

Note: Be prepared to finish this project once you start unless the dwelling is unoccupied.

Load Center Changes
Unit 5

Job Sheet 1—Replace an Existing Interior Flush Mount Load Center

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
All circuits work when supply voltage turned on	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

Note: This job sheet is intended to provide instruction on removing an inadequate or defective load center and replacing it with an appropriate new one. Riser, meter base, and other service equipment will not be dealt with due to the number of variables involved.

Caution: This job should be done on a trainer board, not on a live job site.

A. Equipment and materials

Pouch tools
Keyhole saw
Hacksaw blade or nail saw
Load center with flush cover

Note: If you are increasing the size of the load center use Example No. 1, 1(a), 1(b), or 1(c), from the tables and examples in the back of the *NEC* to compute the size needed.

Drop cloth
Knockout cutter set

Note: If the load center you are changing is fed through a nipple from the meter base and it can be aligned with existing KO's in the new load center you will not need this equipment.

Job Sheet 1

Safety glasses
Voltmeter
Metal tapping screws or pan head wood screws

Note: The length of these screws will be determined by the distance between the panel and the stud. Shims may be needed.

Portable GFCI

B. Procedure

Note: This project must be completed once started. Check with the customer to determine when it would be convenient to have the electricity off for this operation. Be sure there is not any life sustaining medical equipment involved in this outage. Have emergency lighting available.

☐ 1. Gather equipment and materials.

Note: Check to be sure you have every possible item needed to finish the job once you start. Contact utility company. They may want to remove the meter.

☐ 2. Put on safety glasses.

☐ 3. Remove load center cover screws.

☐ 4. Remove load center cover.

Note: Place the cover out of your working areas.

☐ 5. Turn off or pull existing main.

Note: Notify the customer that there will be an outage before disconnecting power.

☐ 6. Pull the meter.

Note: Turning off the main(s) eliminates an arc during this process.

☐ 7. Remove fasteners securing load center to studs.

Caution: If it is secured by screws, use extreme care when working around load center interior.

Job Sheet 1

☐ 8. Trace outline for new load center

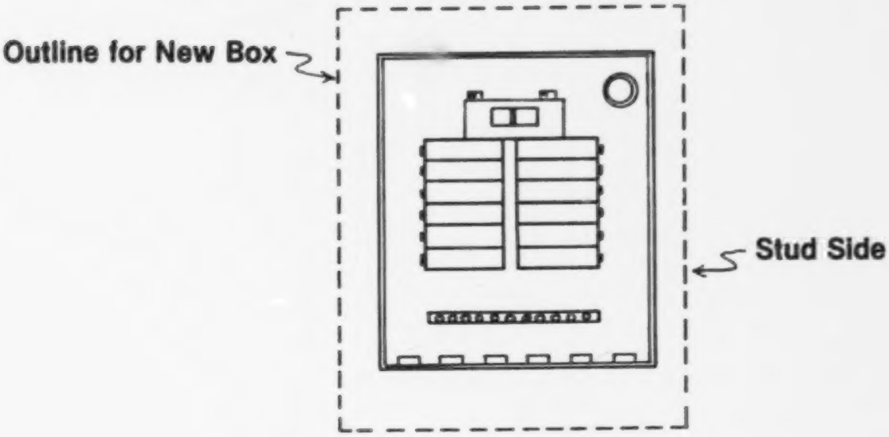
- Hold new load center over existing one.

  Note: Match up knockouts so your panel will fit over existing feeder raceway. You may have to cut an opening.

- Draw around load center once it is in place.

  Note: Make opening about ¼" large on top and bottom of the panel.

Figure 1



☐ 9. Cut opening for new load center.

- Cut lightly along line with knife.
- Repeat cuts until cut is over one half way through plasterboard.

  Note: Do not use a saw until it is evident there are no wires that could be cut.

- Break out plasterboard.

  Note: Dress the opening with the keyhole saw.

☐ 10. Disconnect the service entrance conductors from the load center line lugs.

Job Sheet 1

☐ 11. Disconnect the grounded conductor.

Note: Grounded conductors are always last off and first back on for safety purposes.

☐ 12. Disconnect all wires from branch circuit breakers.

Note: Label all circuits so you can update new circuit directory.

☐ 13. Disconnect all grounded and grounding wires from block.

☐ 14. Remove all locknuts and bushings.

☐ 15. Slip all branch circuit cables out of load center.

Note: This may not be possible until you start pulling the panel from the opening.

☐ 16. Pull load center out of opening.

☐ 17. Lay old load center out of the way.

☐ 18. Punch out appropriate KO's for feeder and branch circuits.

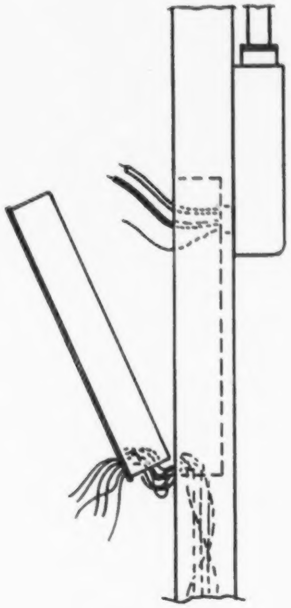
☐ 19. Hold panel up to opening.

Job Sheet 1

☐ 20. Start branch circuit cables into openings.

Note: Readjust cable connectors before starting cables into the panel.

Figure 2



☐ 21. Feed cables in as you move the load center into place.

Note: Proceed carefully so you do not damage any cables.

☐ 22. Guide service entrance conductors into opening.

☐ 23. Move load center into place.

Note: Some installations may require mat frame or trim.

☐ 24. Replace locknut and bushing.

Note: Bond equipment according to the *NEC* and local codes.

☐ 25. Secure load center.

Note: Screws are recommended for this job.

Job Sheet 1

☐ 26. Reconnect service neutral.

☐ 27. Reconnect ungrounded service entrance conductors.

Note: If these conductors are not long enough, replace them.

☐ 28. Reconnect branch circuits.

Note: Be sure and hook conductors to appropriate size breaker.

☐ 29. Turn all disconnects off.

☐ 30. Replace meter.

☐ 31. Turn on main(s).

☐ 32. Turn on branch circuit.

☐ 33. Check circuits.

☐ 34. Put all covers and trims in place.

☐ 35. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

Load Center Changes
Unit 5

Job Sheet 2—Install a Rainproof Load Center to Supplement an Existing Interior Load Center

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
All equipment connections made securely	_____
All circuits work properly when energized	_____
Workmanship	_____
Compliance to *NEC*	_____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

Note: There are many variables involved in this project. It is highly possible that you could do ten jobs like this and have all of them be different. This is only one application ;keep in mind there could be many more. This job sheet is an example of one way to increase circuit capacity for a service when the load calculations show the amperage rating will accept your additional circuits.

Caution: This job should be done on a trainer board, not on a live job site.

A. Equipment and materials

Pouch tools
Rainproof load center

Note: The number of circuits needed and type of disconnect already employed will determine whether this load center needs to have a main.

Feeder wire

Note: Size will be determined by service ampacity and use of the load center.

Job Sheet 2

Raceway to connect load center

Note: If the connection is made with conduit you will need fittings; if made with rigid metal conduit you will need locknuts and bushings.

Fasteners

Note: Screws and anchors should be used on concrete or bricks; metal tapping or wood screws will work on wood

Safety glasses
Pencil
Insulated gloves
Voltmeter
Auxiliary light
Portable GFCI
Drill motor and masonry bit
Wood ladder
Service connectors

Note: If the utility company disconnects the drop, these will not be needed.

Close nipple

Note: The size of this equipment will be determined by the size of the conductors to be installed.

Four locknuts to fit nipple
Two bushings to fit nipple
Feeder wire

Note: This includes ungrounded and grounded; size will be determined by service size.

B. Procedure

Note: Contact the utility company before you start this project. They may want to disconnect service drop from the service entrance conductors.

☐ 1. Gather equipment and materials.

☐ 2. Put on safety glasses.

☐ 3. Notify customer that there will be a temporary outage.

Note: Make sure you will not be disrupting the operation of any life sustaining equipment.

Job Sheet 2

☐ 4. Disconnect the service drop.

- Work from a wooden ladder.
- Wear insulated gloves.
- Disconnect one conductor at a time.
- Tape conductors as you remove them.
- Remove neutral last.

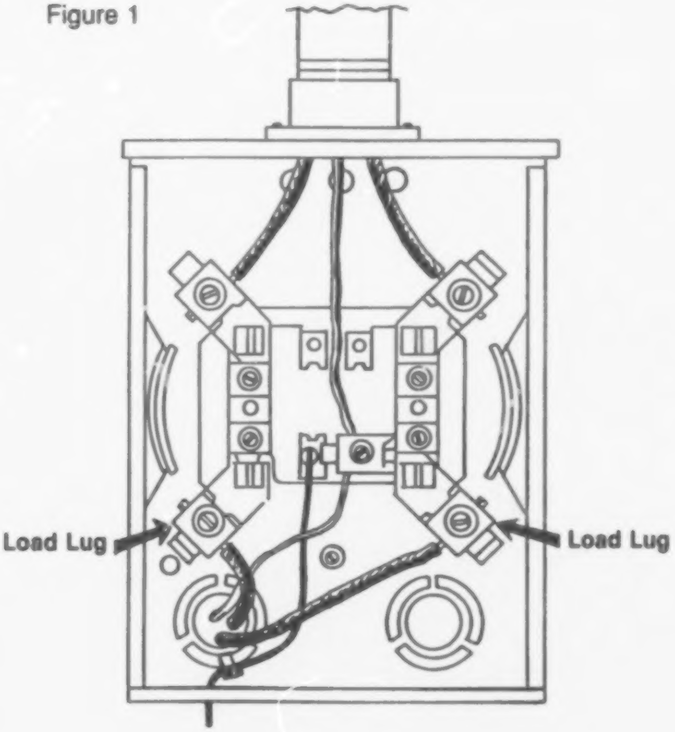
☐ 5. Loosen straps connecting riser to structure.

☐ 6. Remove meter base cover.

☐ 7. Remove screws securing meter base.

☐ 8. Remove ungrounded conductors from load side.

Figure 1



Job Sheet 2

☐ 9. Remove grounded and grounding conductors.

☐ 10. Remove bushing and locknuts.

☐ 11. Straighten conductors.

☐ 12. Pull meter base straight out and over conductors.

☐ 13. Lift meter base out of way.

☐ 14. Remove appropriate KO from load center.

Note: If it is going to put the meter higher than the utility company will allow when you use a bottom KO, use a top one instead. You may have to cut a new one.

☐ 15. Put load center over conductors.

☐ 16. Mark securing screw locations.

☐ 17. Mount the load center.

Note: Be sure and use GFCI if needed.

☐ 18. Install locknuts and bushings.

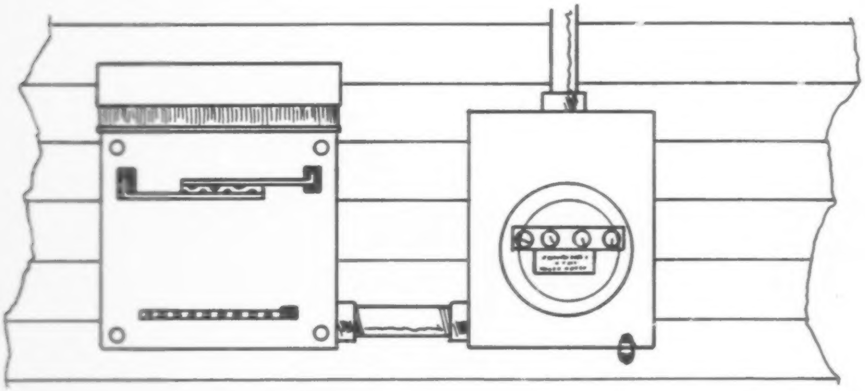
Note: Check on bonding requirements with local authority having jurisdiction.

Job Sheet 2

☐ 19. Install nipple between load center and meter base using backup locknuts on the outside of both enclosures.

Note: It may be that you will have to mount the meter base to the side of your panel instead of above it. See Figure 2. Look the situation over carefully before you decide.

Figure 2



☐ 20. Secure meter base.

☐ 21. Install interior locknuts and bushings.

Note: Check with local utility company on bonding requirements.

☐ 22. Install conductors between existing panel and new load center.

Note: Size is determined by load and equipment calculations. Provide overcurrent protection for existing panel from new load center.

☐ 23. Install conductors between meter load lugs and new load center line lugs.

☐ 24. Reconnect grounding electrode conductor.

☐ 25. Resecure service riser.

Job Sheet 2

☐ 26. Reconnect service drop.

Note: Consult your local utility company; they may want to do this. Always remember:

- Grounded conductor is last off and first back on.
- Wear insulated gloves.
- Work one conductor at a time.
- Tape conductor as it is connected.
- Don't carry extra tools in your hands.
- Work from a wooden ladder.

☐ 27. Turn off main breaker(s).

☐ 28. Install meter.

☐ 29. Turn on breakers.

☐ 30. Check circuits.

☐ 31. Update circuit directory.

☐ 32. Clean work area and put away all equipment and materials.

Evaluator's comments: ____

____

____

SMART HOUSE Wiring
Unit 6

Objective Sheet

Unit Objective

After completing this unit, the student should be able to show how a SMART HOUSE operates and answer questions related to SMART HOUSE wiring. The student should demonstrate these competencies by completing the assignment sheet and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to SMART HOUSE wiring with their correct definitions.
2. Define the term "SMART HOUSE."
3. Draw a diagram showing the operation of a SMART HOUSE.
4. List six features of a SMART HOUSE.
5. Identify blueprint symbols used in SMART HOUSE wiring.
6. Explain the two phases of SMART HOUSE wiring.
7. Match cables used in SMART HOUSE wiring with their characteristics.
8. Explain the five types of outlets used in SMART HOUSEs.
9. Match the components of a service center with their characteristics.
10. Identify special tools used in SMART HOUSE wiring.
11. Use Article 780 of the *National Electrical Code®* to answer questions related to SMART HOUSE wiring. (Assignment Sheet 1)

SMART HOUSE Wiring
Unit 6

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Blueprint Symbols Used in SMART HOUSE Wiring (Objective 2)
   TM 2—Service Center Layout (Objective 6)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment sheet. Review criteria for evaluation of this activity.

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

Suggested Activities

14. Give written test.

15. Record assignment sheet rating and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Collect and show to class several SMART HOUSE blueprints. Point out some of the special symbols that are found on the blueprints, then have students identify other special symbols related to SMART HOUSEs. Skill areas: **listening and oral communication**.

2. Invite a local contractor to class to discuss the two phases of SMART HOUSE wiring and the *NEC* requirements for SMART HOUSEs. Have students prepare questions, in writing, that they would like to have answered and provide list to the speaker so that he/she will be prepared to answer them. Skill areas: **writing, listening, and oral communication**.

3. Invite local suppliers to class to show various tools. Have them demonstrate the proper use and care of the various tools. Give students an opportunity to ask questions during the demonstration. Skill areas: **listening and oral communication**.

4. Demonstrate the proper use and care of special tools used in SMART HOUSE wiring if a local supplier is unavailable.

5. If possible, plan an on-sire visit to a SMART HOUSE under construction to show students the various components of a SMART HOUSE. Have students take notes on what they observe, then discuss their observations in class. Skill areas: **listening, oral communication, and creative thinking**.

6. Use Teacher Supplement 1 to locate SMART HOUSE centers and wholesalers in your area.

7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

Suggested Activities

Resources Used in Developing This Unit

1. *1993 National Electrical Code®.* Quincy, MA: National Fire Protection Association, 1992.
2. SMART HOUSE Information Packet. SMART HOUSE, L.P., 400 Prince George's Boulevard, Upper Marlboro, MD 20772-8731.
3. Stauffer, H. Brooke and Ray C. Mullin. *SMART HOUSE Wiring*. Albany, NY: Delmar Publishers Inc., 1993.

Suggested Supplemental Resources

1. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code®*. Albany, NY: Delmar Publishers Inc., 1993.
2. SMART HOUSE Information Packet. SMART HOUSE, L.P., 400 Prince George's Boulevard, Upper Marlboro, MD 20772-8731.

   Note: For more information concerning SMART HOUSE construction, contact SMART HOUSE, L.P., a consortium of builders, manufacturers, and organizations, at either the above address or by calling 1-301-249-6000.

3. *Welcome to the SMART Life* videotape. Taped at one of the SMART HOUSE demonstration homes, it demonstrates firsthand the system features, benefits, and options. Approximately 10 minutes. To order a copy and check price, call Marketing Dept. (301/249-6000).
4. Stauffer, H. Brooke and Ray C. Mullin. *SMART HOUSE WIRING*. Albany, NY: Delmar Publishers Inc., 1993.

   To order or preview Delmar publications, call or write to:

   Delmar Publishers Inc.
   3 Columbia Circle, P.O. Box 15015
   Albany, NY 12212-5015
   Phone: 1-800-347-7707

5. Electronic House. Advanced Housing and Home Automation. To subscribe to this magazine, call 319/256-2060 or write to:

   Electronic House
   56790 Magnetic Drive
   Mishawaka, IN 46545

Suggested Activities

Instructions for Evaluating Student Performance

Assignment Sheet—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

SMART HOUSE Wiring
Unit 6

Answers to Assignment Sheet 1

1. 780-3 (b)

   Condition 1—A nominal-operation acknowledgement signal is not being received from utilization equipment.

   Condition 2—A ground fault condition exists.

   Condition 3—An overcurrent condition exists.

2. 780-3 (d)

   In the event of a controller malfunction, all associated outlets shall be de-energized.

3. 780-5

   For signaling circuits not exceeding 24 volts, the current required shall not exceed one ampere where protected by an overcurrent device or an inherently limited power source.

4. 780-2 (a)

   Except as modified by the requirements of this article, all other applicable articles of this code shall apply.

5. 780-7

   Receptacles, cord connectors, and attachment plugs used on closed-loop power distribution systems shall be constructed so that they are not interchangeable with other receptacles, cord connectors, and attachment plugs.

SMART HOUSE Wiring
Unit 6

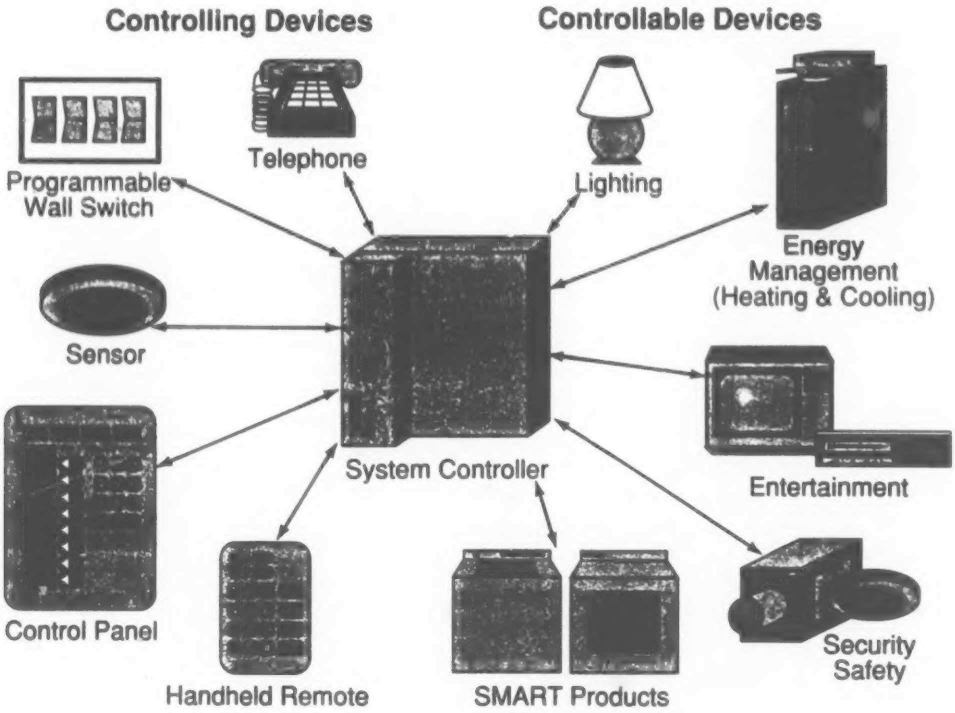
Answers to Written Test

1.

a.	4	g.	11	m.	12
b.	6	h.	10	n.	13
c.	2	i.	9	o.	15
d.	3	j.	8	p.	16
e.	5	k.	7	q.	17
f.	1	l.	14	r.	18

2. A home management system that combines today's latest technology with an integrated home network of energy, communication, audio/visual, and telephone cables.

3. Diagram should represent operation as shown below.


Controlling Devices
Controllable Devices
Programmable Wall Switch
Telephone
Lighting
Energy Management (Heating & Cooling)
Sensor
Entertainment
Control Panel
System Controller
Handheld Remote
SMART Products
Security Safety

Answers to Written Test

4. Answer may include any six of the following:

    a. Security/safety
    b. Air comfort
    c. Energy management
    d. Entertainment
    e. Lighting
    f. Gas energy
    g. SMART appliances
    h. Home office
    i. Bells and whistles

5. a. Fixture switch block
    b. Telephone/coax outlet with terminator
    c. Dimmer switch block
    d. GFCI duplex receptacle
    e. Applications outlet
    f. Telephone/coax outlet
    g. Dual switch
    h. Blank (no block installed)
    i. Distribution interface unit
    j. Duplex receptacle
    k. Terminator
    l. Wall switch
    m. Sensor outlet
    n. Switched duplex receptacle
    o. Quad switch

6. Answers may be in student's own words, but should include the following:

    a. Phase 1 (SMART-REDI wiring)—During construction, the basic SMART HOUSE wiring system is installed which provides full electrical service to a house; this wiring system provides special features not available through conventional wiring.

    b. Phase 2 (SMART upgrade)—Either immediately following installation of the SMART-REDI wiring system (Phase 1) or when the homeowners choose to upgrade the basic wiring system, intelligent components such as the system controller electronics and SMART receptacles are installed and programmed to provide full home automation capability.

7. a. 4
    b. 3
    c. 1
    d. 2

Answers to Written Test

8. Answers may be in student's own words, but should include the following:

   a. Convenience center

   - A combination wall outlet designed to replace conventional outlets
   - Requires a two-gang box and will accept any combination of two of the following wiring devices:

     - Duplex receptacle
     - GFCI duplex receptacle block
     - Switched duplex receptacle block
     - Fixture/switch block
     - Dimmer/switch block
     - Integrated telecommunications/coaxial outlet
     - Hybrid cable terminator

   b. Switch/sensor outlets

   - Consist of mounting bracket and face plate and switch/sensor connector
   - Requires no box due to its low-voltage application
   - Available in single, dual, and quad versions
   - Connected to convenience center via applications cable

   c. Applications outlet

   - Installed on applications bus (12-volt DC dedicated circuits)
   - Provides power and control signals to control panels, ambient light sensors and motion detectors (devices that do not require AC power)

   d. Distribution interface unit

   - Serves as a junction and/or distribution point for communications cable
   - Consists of a 4-way splitter/combiner for coaxial cable and telephone wiring
   - Usually located in service spaces such as garages, closets, or basements

   e. Conventional outlets

   - Permanently mounted fixtures and small appliances such as fans are wired with conventional NM cable and outlet boxes
   - A switch/sensor outlet is installed near the outlet for SMART upgrade purposes
   - Outdoor outlets use traditional GFCI outlets

Answers to Written Test

9. a. 4
   b. 1
   c. 2
   d. 6
   e. 5
   f. 7
   g. 3

10. a. Barrel terminal insertion tool
    b. Application cable tap tool
    c. Coaxial cable stripper
    d. Cable slitter
    e. Coaxial cable crimper
    f. Hybrid branch cable tap tool

SMART HOUSE Wiring
Unit 6

Written Test

Name ______________________________________ Score ________________

1. Match the terms related to SMART HOUSE wiring on the right with their correct definitions.

    ______a. A multifunctional outlet including a branch cable tap and one or more of the following; duplex receptacle block, fixture block, dimmer block, hybrid cable terminator, or a telephone/coaxial outlet; may be in SMART version or SMART-REDI version

    ______b. Up to 200 feet of hybrid branch cable with as many as 30 nodes; operates from the load center and the system controller

    ______c. A one to four splitter/combiner for two coaxial cables and eight telephone conductors in a SMART HOUSE communications cable

    ______d. A low voltage outlet for sensors, wall switches and various devices that communicate over the SMART HOUSE network and require 120 volt DC; applications outlets are not active during the SMART-REDI phase

    ______e. A cable that consists of two coaxial cables and four pairs of telephone conductors

    ______f. A single run of applications cable with all applications bus outlets; applications busses are terminated at the system controller connector board

    1. Applications bus
    2. Distribution interface unit
    3. Applications outlet
    4. Convenience center
    5. Communications cable
    6. Hybrid branch circuit

Written Test

______g. Contains a branch slave chip and will allow conventional low voltage products such as relays and sensors to be operated by the system controller

______h. The SMART user interface; includes visual display and input terminal

______i. A ribbon-type cable that consists of three #12 AWG conductors and six #24 AWG low voltage control wires

______j. A ribbon cable consisting of two #18 AWG conductors used for 12-VDC power, and six #24 AWG conductors used as low voltage control conductors

______k. A combination RF signal combiner/amplifier; receives signal from various inputs, i.e. VCR's, video cameras located inside the house; it distributes the signal throughout the house

______l. Permits homeowners and service providers to control the SMART HOUSE or request data by a touch-tone phone; usually includes a voice mail system and intercom system

______m. Similar to a conventional circuit breaker load center, but contains a cutout that adapts to the opening in the service center cable manager; all hybrid branch circuits are protected with a 30mA GFCI breaker

______n. Location of all electrical and communications distribution controllers

______o. Term that refers to SMART HOUSE products that are incapable of communicating with the system controller

7. Coaxial headend
8. Applications cable
9. Hybrid branch cable
10. Control panel
11. Input/output mode
12. Load center
13. Service center
14. Telephone gateway
15. SMART-REDI

Written Test

______p.	A low voltage wall switch outlet	16. Switch/sensor outlet
______q.	Referred to as the "brain" of the system, it manages all SMART HOUSE system functions	17. System controller
		18. SMART appliance
______r.	An appliance that is capable of communicating with the system controller	

2. Define the term "SMART HOUSE".

____

____

____

3. Draw a diagram, in the space provided below, showing the operation of a SMART HOUSE.

Written Test

4. List six features of a SMART HOUSE.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

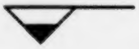
f. ______________________________

5. Identify blueprint symbols used in SMART HOUSE wiring by writing the symbol designation in the blank provided under each symbol.

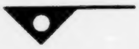
Duplex receptacle
GFCI duplex receptacle
Switched duplex receptacle
Telephone coax outlet
Telephone coax outlet with terminator

Fixture switch block
Dimmer switch block
Blank (no block installed)
Terminator
Wall switch
Dual switch

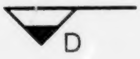
Quad switch
Sensor outlet
Distribution interface unit
Applications outlet



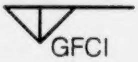
a. ______________



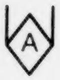
b. ______________



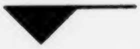
c. ______________



d. ______________



e. ______________



f. ______________

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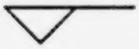
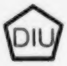
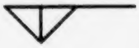
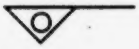




g. ________________ h. ________________ i. ________________





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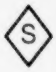
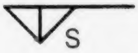
j. ________________ k. ________________ l. ________________





$$$$

m. ________________ n. ________________ o. ________________

6. Explain the two phases of SMART HOUSE wiring.

Phase 1:

a. (SMART-REDI) ____

____

____

____

Written Test

Phase 2:

b. (SMART-Upgrade) ____

____

____

____

7. Match cables used in SMART HOUSE wiring on the right with their characteristics.

______a. Used for power and control wiring; Contains three #12 AWG copper conductors (ground, neutral, and hot); Contains six #24 AWG class 2 control conductors.

______b. Types NM and UF cables are used to power all lighting fixtures and hard wired appliances.

______c. Used for low voltage control wiring; a flat ribbon cable containing six #24 AWG class 2 signaling conductors, and two #18 AWG conductors for distribution of 12 Volt DC power.

______d. Marked CM or CMX; contains two 75Ω coaxial cables and eight telephone wires.

1. Applications cable
2. Communications cable
3. Conventional cable
4. Hybrid branch cable

8. Explain the five types of outlets used in SMART HOUSEs.

a. Convenience center ____

____

____

b. Switch/sensor outlets ____

____

____

Written Test

c. Applications outlets ____

____

____

d. Distribution interface unit ____

____

____

e. Conventional outlets

____

____

9. Match components of a service center on the right with their characteristics.

______a.	Rated 240/120 volt single-phase three wire; will accept remote control circuit breakers that will allow the system controller to turn them on and off for energy management	1. Cable manager 2. Coaxial headend 3. Input/output module
______b.	A "T" shaped enclosure with two sections, the header and lateral; covered under Article 780 of the *NEC*; exempt from the requirements of Article 362-5	4. Load center and surge protector 5. System controller 6. Telephone gateway
______c.	An amplifier that distributes an amplified signal to all coax outlets in the house; contains sixteen outlet ports for eight pairs of cables	7. Twelve-volt DC power supply
______d.	Distributes signals to all telephone outlets in the house; may serve a maximum of 32 phone outlets in the house; connected via computer cable to the system controller	
______e.	Contains a connecting board used to terminate applications cables and #24 control wires from the hybrid branch cables	

Written Test

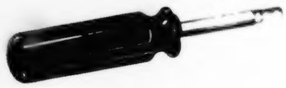
_______f. A class 2 device that powers the system controller; available in solid state and battery backup models

_______g. A device that allows conventional products that operate either 12-volts DC or 24-volts AC to send signal and receive commands from the system controller

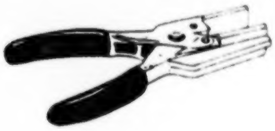
10. Identify special tools used in SMART HOUSE wiring by writing the tool name in the blank provided under each illustration.

Cable slitter
Hybrid branch cable tap tool
Application cable tap tool

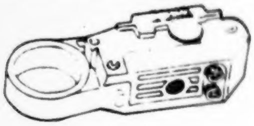
Barrel terminal insertion tool
Coaxial cable stripper
Coaxial cable crimper



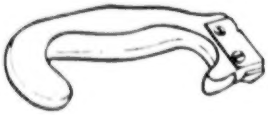
a. ______________________________



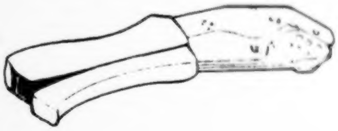
b. ______________________________



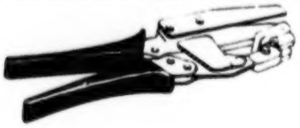
c. ______________________________



d. ______________________________



e. ______________________________



f. ______________________________

***Permission to duplicate this test is granted.**

SMART HOUSE Wiring
Unit 6

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Use Article 780 of the *National Electrical Code®* to Answer Questions Related to SMART HOUSE Wiring Rating _____

Comments: ____

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

SMART HOUSE Wiring
Unit 6

Teacher Supplement 1 — SMART HOUSE SALES & SERVICE PROVIDERS, AND DISTRIBUTORS

Listed below, by type of business, are organizations authorized to provide products and/or services to support the construction of SMART HOUSES.

AUTHORIZED SALES AND SERVICE PROVIDERS: A national sales and service network specializing in the SMART HOUSE System who are trained and equipped to offer a full range of services including but not limited to: System Sales, Product Inventory, Design Layout, Installation, Upgrade, Configuration, Maintenance, Warranty, and Service.

SMART HOUSE CENTERS

For information on the representative in your area call (203) 371-4448.

ELECTRICAL WHOLESALERS: Distributors who inventory and sell electrical products installed by electrical contractors and/or dealers including but not limited to: Cable, Outlet Devices, Switches, and Service Entrance Equipment.

Arizona
Capital Electric Supply
  Phoenix (602) 266-5342

California
Current Supply, Inc.
  Santa Ana (714) 893-1299
Electric Supply of Napa
  Vallejo (707) 252-1987
  Fairfield (707) 252-1987
  Napa (707) 252-1987
Norcal Electric Supply, Inc.
  Fairfield (707) 426-3733
  Napa (707) 257-1872
Valley Electric Co., Inc.
  Stockton (209) 946-8100
  Sacramento (209) 946-8100
  Modesto (209) 946-8100

Connecticut
Graco Electrical Supplies, Inc.
  Hartford (203)627-9351
Mass. Gas Electric Specialty
  Hartford (617) 625-6400
  New Haven (617) 625-6400

Florida
Ace Electric Supply Company
  Jacksonville (904) 731-5900
Mayer Electric Supply Co., Inc.
  Tampa (813) 620-4114
Mid-Florida Supply, Inc.
  Orlando (407) 425-8633
Pennisular Elec. Distributors Inc.
  W. Palm Beach (407) 832-1626
Southwest Elec. Supply of Naples
  Naples (813) 263-6009

Georgia
Cameron & Barkley Company
  Atlanta (404) 446-1101
Goforth Electrical Supply, Inc.
  Atlanta (404) 536-3361

Illinois
Moline Electric Supply Company
  Moline (309) 797-3361

Kansas
Stanion Wholesale Electric
  Kansas City (913) 829-8111

Louisiana
Elliott Electric Supply Co.
  Shreveport (214) 320-2941

Mayrland/Washington, DC
Branch Group Incorporated
  Baltimore (410) 727-0711
  Washington, DC (301) 249-5005
Interstate Electric Supply Co., Inc.
  Baltimore (410) 944-6700

Massachusetts
Mass. Gas/Electric Specialty
  Boston (617) 625-6400
  Worcester (617) 625-6400
Standard Electric Supply Co., Inc.
  Boston (508) 658-5050

Michigan
Englewood Electric Supply
  Jackson (517) 782-7121
Michigan Chandelier Co.
  Detroit (313) 651-4302
Ray Electric
  Detroit (313) 739-9700

Minnesota
United Electric
  Minneapolis (612) 338-1915

Missouri
Frost Electric Supply Co.
  St. Louis (314) 567-4004
Loyd's Electric Supply, Inc.
  Springfield (417) 334-2171

Teacher Supplement 1

Nevada
Vegas Electric Supply Company
Las Vegas (702) 367-0980

New Hampshire
Mass. Gas/Electric Specialty
Manchester (617) 625-6400

New Hampshire
Mass. Gas/Electric Specialty
Nashua (617) 625-6400
Standard Electric Supply, Co.
Nashua (508) 658-5050

New Jersey
Warshauer Electric Supply Co.
Monmouth (908) 741-6400
Ocean (908) 741-6400

New Mexico
National Electric Supply Co., Inc.
Albuquerque (505) 345-3577

New York
ASKCO Electric Supply Co.
Albany (518) 798-9503
Schenectady (518) 798-9503
Avon Electrical Supplies, Inc.
Nassau (516) 582-4770
Suffolk County (516) 582-4770
DUPLEX Electric Supply Corp.
Port Washington (516) 625-8181
Shanor Electric Supply, Inc.
Buffalo (716) 876-0711
Schwing Electrical Supply Corp.
Nassau (516) 727-1155
Suffolk County (516) 727-1155

North Carolina
Hornet's Nest Electrical Sup. Co.
Charlotte (704) 376-4828
Ligon Electric Supply Sup. Co.
Winston-Salem (919) 723-9656

Ohio
Apex Electric Supply Co., Inc.
Akron (216) 253-5157
The Johnson Electric Supply Co.
Cincinnati (513) 421-3700
Wiseway Plumbing, Elec. & Lighting
Cincinnati (606) 371-2211
Basic Distribution Corp.
Columbus (614) 777-2000
Englewood Electric Supply
Toledo (419) 476-9006
Mars Electric Company
Cleveland (216) 946-2250
Superior Electric Supply Co.
Cleveland (216) 323-5451

Oklahoma
Star Electric Supply Company
Tulsa (918) 835-7672

Oregon
North Coast Electric Company
Portland (206) 454-1747
Taylor Electric Supply, Inc.
Portland (503) 233-5321

Pennsylvania
Fluorescent Supply Company
Harrisburg (717) 233-8401
Lebanon (717) 233-8401
Carlisle (717) 233-8401
York (717) 233-8401
Kay Electric Supply Company
Philadelphia (215) 382-0500
West Chester Electric & Electronics
Lancaster (717) 397-8221

Rhode Island
Mass. Gas/Electric Specialty
Providence (617) 625-6400

Tennessee
Harris Electric Supply Co., Inc.
Nashville (615) 255-4161

Texas
SMART HOUSE Electrical Supply
Houston (713) 861-7283
Elliott Electric Supply, Inc.
Ft. Worth (214) 320-2941
Houston (713) 675-6700
Dallas (214) 320-2941

Virginia
Dixie Electric Supply Corp.
Richmond (804) 355-8003
Interstate Electric Supply Co., Inc.
Chantilly (703) 631-2500
United Electric Supply Corp.
Virginia Beach (804) 595-1186
Norfolk (804) 595-1186

Washington
North Coast Electric Company
Seattle (206) 454-1747

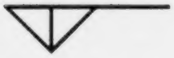
Wisconsin
B - J Electric Supply, Inc.
Madison (608) 257-4777
Best Electric Supply Corporation
Milwaukee (414) 545-8800
Lappin Electric Company
Milwaukee (414) 276-7878

Canada
EECOL Electric Ltd.
Calgary, Alberta (403) 253-1952
EECOL Electric Ltd.
Vancouver, Victoria
(403) 253-1952
Electrical Wholesalers Calgary Ltd.
Calgary, Alberta (403) 250-7060
Guillevin International, Inc.
Toronto, Ontario (416) 670-8433

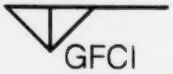
Issue Date: April 14, 1993

Courtesy of SMART HOUSE, L.P.

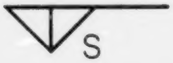
Blueprint Symbols Used in SMART HOUSE Wiring



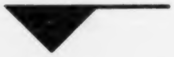
Duplex Receptacle



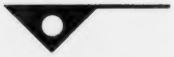
GFCI Duplex Receptacle



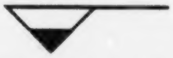
Switched Duplex Receptacle



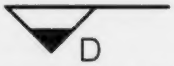
Telephone/Coax Outlet



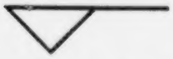
Telephone/Coax Outlet with Terminator



Fixture/Switch Block



Dimmer Switch Block



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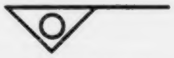

Terminator

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Wall switch

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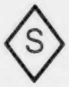
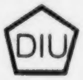
Dual Switch

$$$$

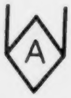
Quad Switch



Sensor Outlet

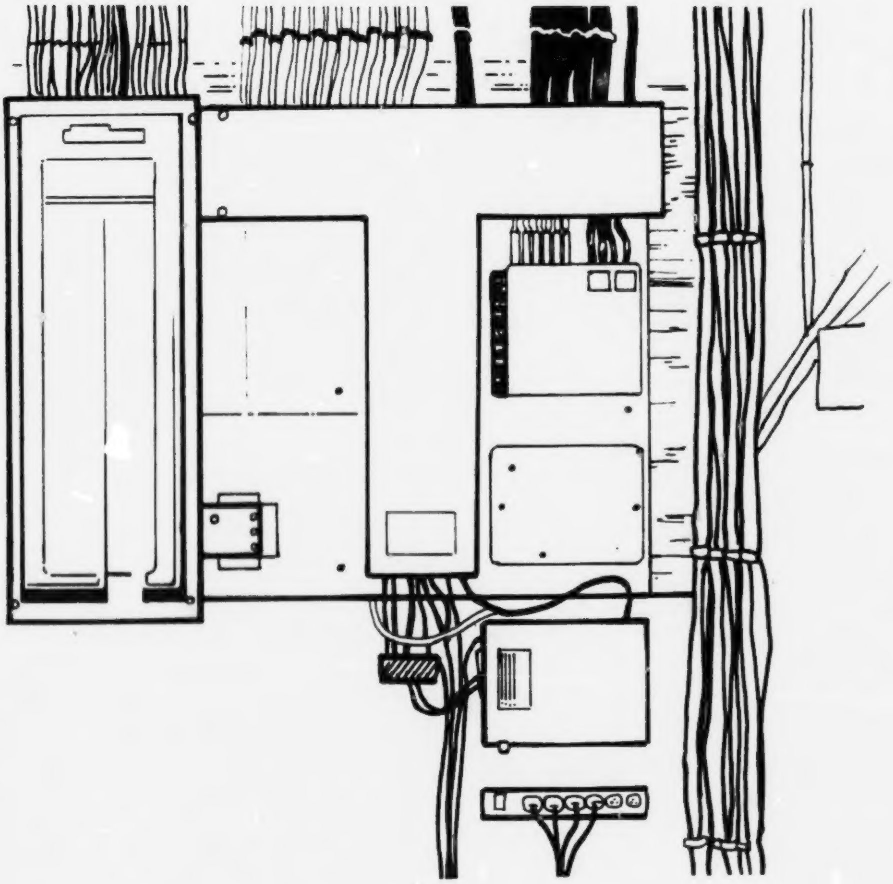


Distribution Interface Unit



Applications Outlet

Service Center Layout



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SMART HOUSE Wiring
Unit 6

Information Sheet

1. **Terms and definitions**

    a. **Applications bus (applications branch)**—A single run of applications cable with all applications bus outlets; applications busses are terminated at the system controller connector board

    b. **Applications cable**—A ribbon cable consisting of two #18 AWG conductors used for 12-VDC power, and six #24 AWG conductors used as low voltage control conductors

    c. **Applications outlet**—A low voltage outlet for sensors, wall switches, and various devices that communicate over the SMART HOUSE network and require 120 volt DC; applications outlets are not active during the SMART-REDI phase

    d. **Coaxial headend**—A combination RF signal combiner/amplifier; receives signal from various inputs, i.e. VCR's, video cameras located inside the house; it distributes the signal throughout the house

    e. **Communications cable**—A cable that consists of two coaxial cables and four pairs of telephone conductors

    f. **Control panel**—The SMART user interface; includes visual display and input terminal

    g. **Convenience center**—A multifunctional outlet including a branch cable tap and one or more of the following; duplex receptacle block, fixture block, dimmer block, hybrid cable terminator, or a telephone/coaxial outlet; may be in SMART version or SMART-REDI version

    h. **Distribution interface unit (DIU)**—A one to four splitter/combiner for two coaxial cables and eight telephone conductors in a SMART HOUSE communications cable

    i. **Hybrid branch cable**—A ribbon-type cable that consists of three #12 AWG conductors and six #24 AWG low voltage control wires

    j. **Hybrid branch circuit**—Up to 200 feet of hybrid branch cable with as many as 30 nodes; operates from the load center and the system controller

    k. **Input/output mode**—Contains a branch slave chip and will allow conventional low voltage products such as relays and sensors to be operated by the system controller

Information Sheet

l. **Load center**—Similar to a conventional circuit breaker load center, but contains a cutout that adapts to the opening in the service center cable manager; all hybrid branch circuits are protected with a 30mA GFCI breaker

m. **Service center**—Location of all electrical and communications distribution controllers

n. **SMART appliance**—An appliance that is capable of communicating with the system controller

o. **SMART-REDI**—Term that refers to SMART HOUSE products that are incapable of communicating with the system controller

p. **Switch/sensor outlet**—A low voltage wall switch outlet

q. **System controller**—Referred to as the "brain" of the system; it manages all SMART HOUSE system functions

r. **Telephone gateway**—Permits homeowners and service providers to control the SMART HOUSE or request data by a touch-tone phone; usually includes a voice mail system and intercom system

2. **Definition of a SMART HOUSE**—A home management system that combines today's latest technology with an integrated home network of energy, communication, audio/visual, and telephone cables

3. **Operation of a SMART HOUSE**

Note: The following steps take place instantaneously once an action has been entered.

a. Individual requests an action and enters on a controlling device.

b. Controlling device sends request to system controller.

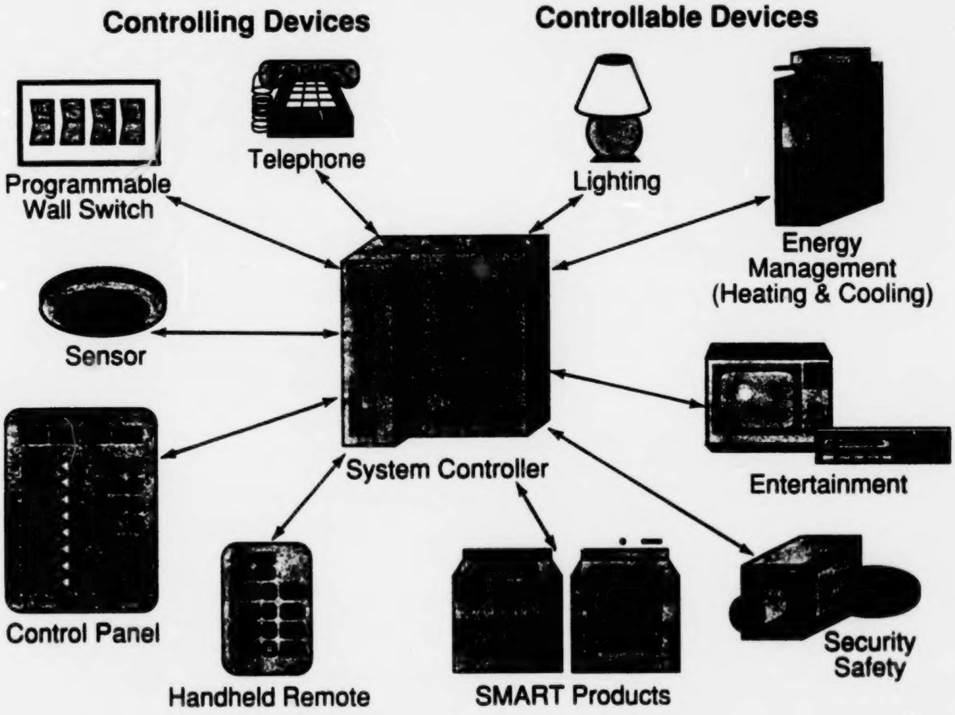
c. System controller sends command to appropriate controllable device.

d. Controllable device sends "action completed" message back to system controller.

e. System controller sends "request completed" message back to controlling device and, if a control panel or handheld remote has been used, it notifies individual that action has been completed.

Note: This SMART control system provides two-way communication between the system controller, SMART products, and controlling devices.

Information Sheet


Controlling Devices
Controllable Devices
Programmable Wall Switch
Telephone
Lighting
Energy Management (Heating & Cooling)
Sensor
System Controller
Entertainment
Control Panel
Handheld Remote
SMART Products
Security Safety

4. Features of a SMART HOUSE

Note: SMART HOUSE, L.P. reports that many features are available today; others are under development and will be available in the future.

a. Security/Safety—Includes video monitoring, automatic dial-out to police or monitoring station, TV display of security/safety messages, lighted exit paths, and zoned security

b. Air comfort—Allows for better temperature control throughout the house via zone controls

c. Energy management—Enhanced by on/off controls (remote, direct, or programmed), setback control, load management, and remote meter reading

Information Sheet

d. Entertainment—Includes whole-house video distribution from outside signals, in-house video distribution and monitoring, and audio distribution and programmable control

Examples: One cable hook-up can distribute programs to all TVs in the home; and a videotape in a VCR can be viewed on any TV in the home.

e. Lighting—Includes multi-way dimming and switching, remote control, mood setting, pre-set lighting levels, light groupings, and programmable lighting by time, mode, or action response

f. Gas energy—Includes SMART heating equipment, water heaters, gas grills, and gas fireplaces

g. SMART appliances—Includes appliances such as washers, dryers, dishwashers, and ovens which are able to communicate with each other or to the system

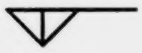
Examples: Message is sent to alert an individual when the laundry has been dried or when the roast is done in the oven; the SMART appliance can also alert an individual when there is a diagnostic problem and repairs may be needed.

h. Home office—Allows for four incoming telephone lines with as many as 32 telephone outlets, which may include a dedicated line for FAX or modem

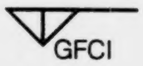
i. Bells and whistles—Includes automated products such as motorized draperies, skylights, electronic door locks, outdoor sprinklers, etc.

5. Blueprint symbols used in SMART HOUSE wiring

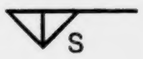
a. Duplex receptacle



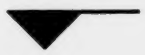
b. GFCI duplex receptacle



c. Switched duplex receptacle

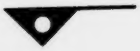


d. Telephone/Coax outlet

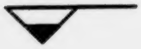


Information Sheet

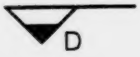
e. Telephone/Coax outlet with terminator



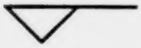
f. Fixture/switch block



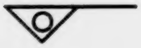
g. Dimmer switch block



h. Blank (no block installed)



i. Terminator



j. Wall switch

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k. Dual switch

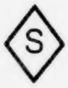
$$

l. Quad switch

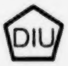
$$$$

Information Sheet

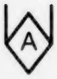
m. Sensor outlet



n. Distribution interface unit



o. Applications outlet



6. Two phases of SMART HOUSE wiring

Note: This two-phase process allows the homeowners to gradually add SMART HOUSE features that they need or want to their house.

a. Phase 1 (SMART-REDI wiring)—During construction, the basic SMART HOUSE wiring system is installed which provides full electrical service to a house; this wiring system provides special features not available through conventional wiring.

Note: SMART-REDI wiring products such as cables, outlets, and distribution equipment must be used to allow for system upgrades in Phase 2.

b. Phase 2 (SMART upgrade)—Either immediately following installation of the SMART-REDI wiring system (Phase 1) or when the homeowners choose to upgrade the basic wiring system, intelligent components such as the system controller electronics and SMART receptacles are installed and programmed to provide full home automation capability

Note: SMART upgrade allows homeowners to communicate with their SMART HOUSE system via telephone, control panel, and remote control and allows SMART appliances to communicate with the system and with each other to carry out specific commands.

Information Sheet

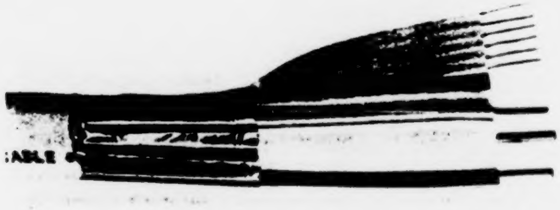
7. Cables used in SMART HOUSE wiring

a. Hybrid branch cable

- Used for power and control wiring
- Contains three #12 AWG copper conductors (ground, neutral, and hot)
- Contains six #24 AWG class 2 control conductors

  Note: These control conductors are in a flat ribbon cable that is located inside the outer protective wrap of the cable.

- To eliminate EMI (electromagnetic interference) the control wiring is wrapped in a foil shield. A #18 copper drain wire is used to maintain the continuity of the shield.
- Article 780-6 of the *National Electrical Code®* covers this cable.



Hybrid Branch Cable

Photo Courtesy of Alcatel Canada Wire

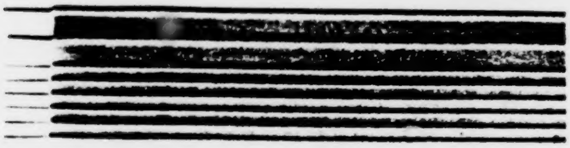
b. Communications cable

- Used for telephone and coax communications
- Marked CM or CMX
- Contains two 75Ω coaxial cables and eight telephone wires

  Note: The telephone wires are divided into four twisted pairs. They are twisted to eliminate any interference from electric motors, fluorescent lights etc.

- The coaxial network is an "upstream-downstream" network. It uses two coaxial cables to each outlet. The downstream cable is black and the upstream cable is white.

Information Sheet



Communications Cable

Photo Courtesy of Alcatel Canada Wire

c. Applications cable

- Used for low voltage control wiring
- A flat ribbon cable containing six #24 AWG class 2 signaling conductors, and two #18 AWG conductors for distribution of 12 Volt DC power
- Used for applications bus, powers 12 Volt DC products such as control panels, smoke detectors, and motion sensors
- Used to connect major appliances to the control subsystem for energy management purposes
- Used for low voltage switching of small equipment lighting fixtures

Applications Cable

Photo Courtesy of Alcatel Canada Wire

d. Conventional cables—Types NM and UF cables are used to power all lighting fixtures and hard wired appliances.

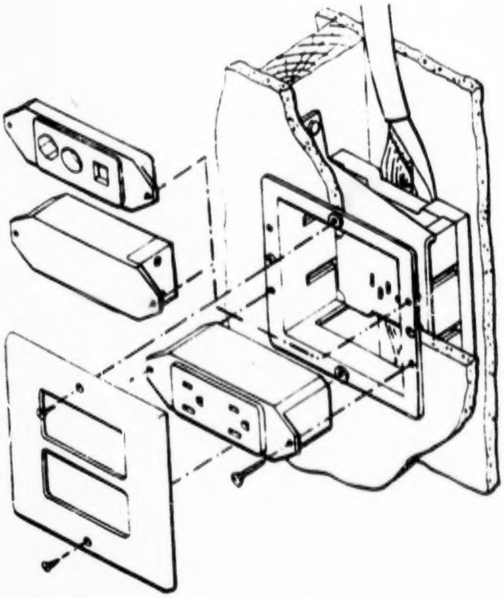
Information Sheet

8. Types of outlets used in SMART HOUSEs

a. Convenience center

- A combination wall outlet designed to replace conventional outlets
- Requires a two-gang box and will accept any combination of two of the following wiring devices:

  - Duplex receptacle box
  - GFCI duplex receptacle block
  - Switched duplex receptacle block
  - Fixture/switch block
  - Dimmer/switch block
  - Integrated telecommunications/coaxial outlet
  - Hybrid cable terminator



Convenience Center

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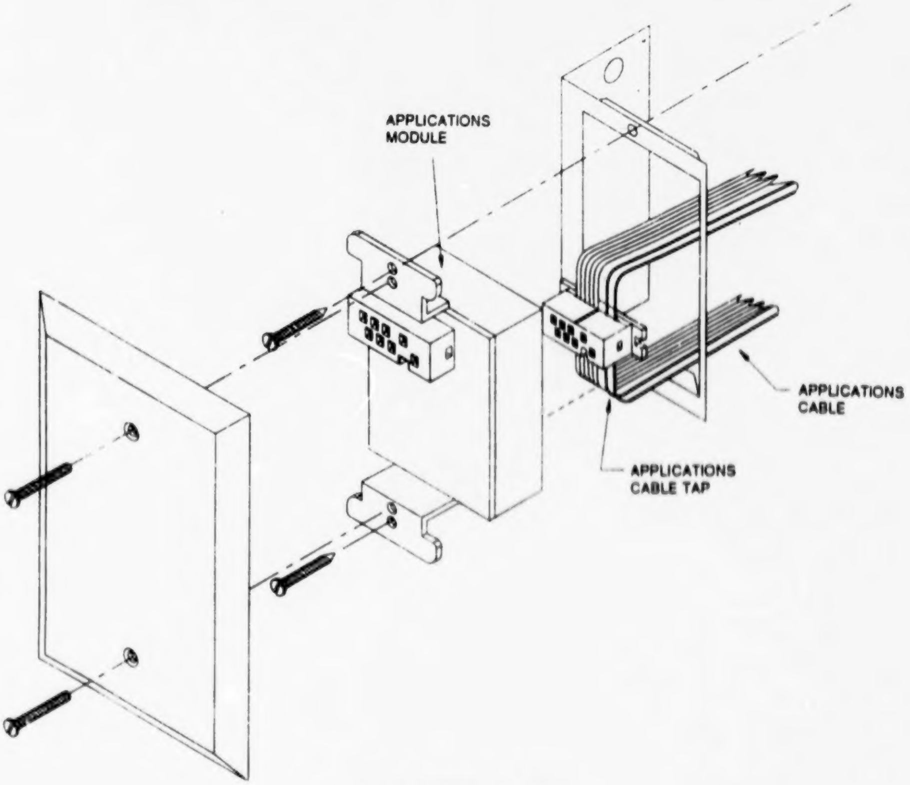
Information Center

b. Switch/sensor outlets

- Consist of mounting bracket and face plate and switch/sensor connector
- Requires no box due to its low-voltage application
- Available in single, dual, and quad versions
- Connected to convenience center via applications cable

c. Applications outlet

- Installed on applications bus (12-volt DC dedicated circuits)
- Provides power and control signals to control panels, ambient light sensors, and motion detectors (devices that do not require AC power)



Applications Outlet

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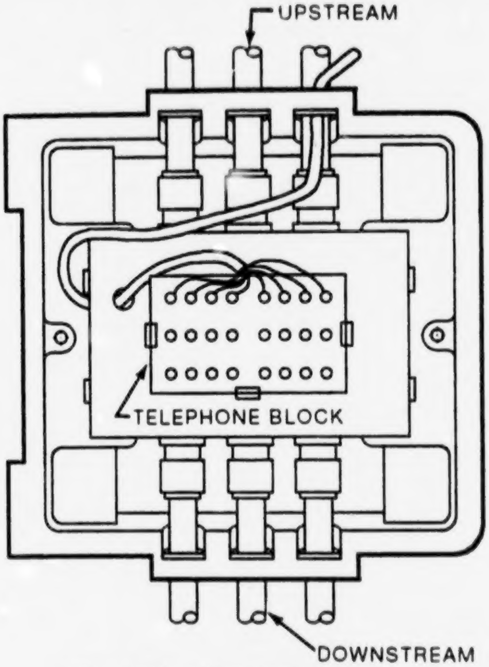
Information Sheet

d. Distribution interface unit

- Serves as a junction and/or distribution point for communications cable
- Consists of a 4-way splitter/combiner for coaxial cable and telephone wiring
- Usually located in service spaces such as garages, closets, or basements



Distribution Interface Unit

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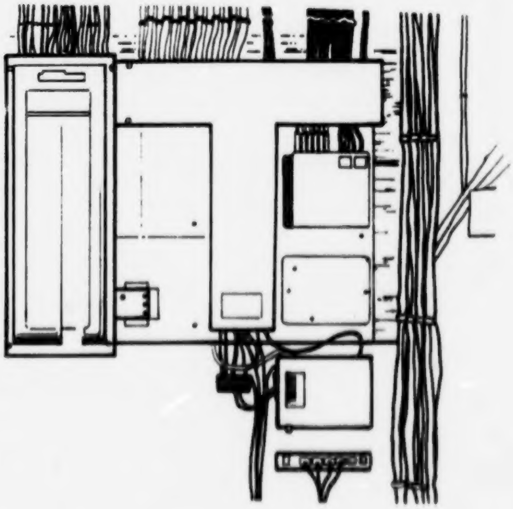
e. Conventional outlets

- Permanently mounted fixtures and small appliances such as fans are wired with conventional NM cable and outlet boxes
- A switch/sensor outlet is installed near the outlet for SMART upgrade purposes
- Outdoor outlets use traditional GFCI outlets

Information Sheet

9. Components of a service center

Note: The service center is the combination utilities service entrance for a SMART HOUSE.



Service Center

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a. Cable manager

- A "T" shaped enclosure with two sections, the header and lateral
- All cables from the SMART HOUSE enter the cable manager, and are then routed to other components
- Contains an integral bonding busbar and a receptacle outlet strip
- Covered under Article 780 of the *NEC*
- Exempt from the requirements of Article 362-5

Information Sheet

b. Load center and surge protector

- SMART HOUSE load centers are rated 240/120 volt single-phase three wire
- Similar to conventional load centers with the following exceptions:

  - Surge protection is included to protect electronic equipment
  - 30 mA ground-fault breakers are used on all hybrid branch circuits. These do not replace the 5mA GFCI's required by the *NEC*
- SMART HOUSE load centers include a rectangular cutout that matches up to the cable manager
- The SMART HOUSE load center will accept remote control circuit breakers that will allow the system controller to turn them on and off for energy management

c. System controller

- Contains a connecting board used to terminate applications cables and #24 control wires from the hybrid branch cables
- Fourteen-branch model has 14 plug-in connectors for terminating applications cable and control wire; eight of these terminations will supply 12-volt DC for applications bus
- Thirty-branch model contains 30 plug-in connectors for termination of application cable or control wire; eight of these also provide 12-volt DC for application bus

d. Telephone gateway

- Distributes signals to all telephone outlets in the house
- May serve a maximum of 32 phone outlets in the house
- Connected via computer cable to the system controller
- Is possible to control the house from any touch-tone phone after a SMART upgrade has been performed

e. Coaxial headend

- An amplifier that distributes an amplified signal to all coax outlets in the house
- Contains sixteen outlet ports for eight pairs of cables

f. Twelve-volt DC power supply

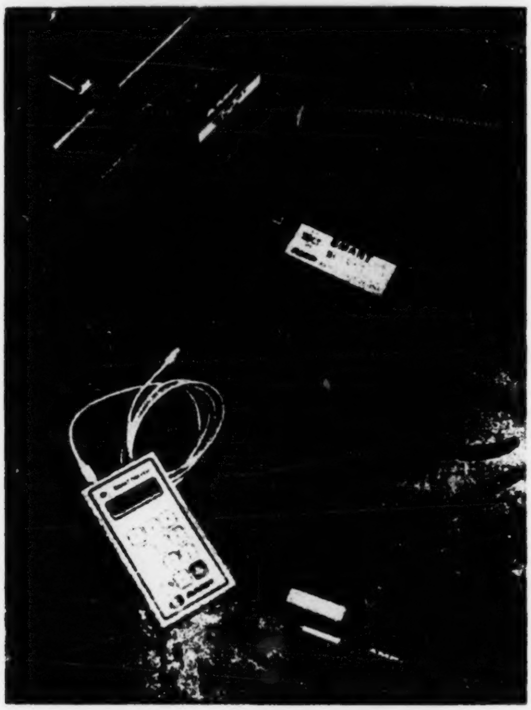
- A class 2 device that powers the system controller
- Available in solid state and battery backup models
- AC power for the 12-volt DC power supply comes from the outlet strip in the cable manager

Information Sheet

g. Input/Output module

- A device that allows conventional products that operate either 12-volts DC or 24-volts AC to send signal and receive commands from the system controller
- Includes motor operated skylights, doorbells, door locks, etc.

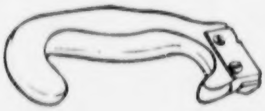
10. Special tools used in SMART HOUSE wiring



SMART HOUSE Specialty Tools

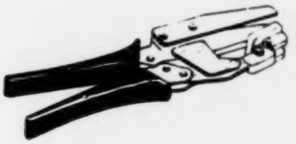
Photo Courtesy of AMP.

a. Cable slitter—Used to cut the outer protective cover of a hybrid cable without damage to the flat ribbon or the foil shield

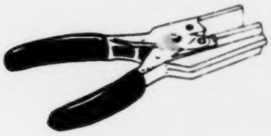


Information Sheet

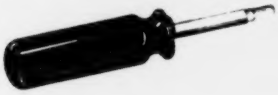
b. Hybrid branch cable tap tool—Used to terminate hybrid branch cables at the convenience center



c. Application cable tap tool—Used to terminate application cables with either an applications cable tap or a switch sensor connector

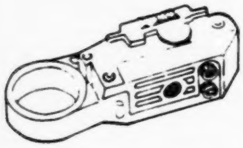


d. Barrel terminal insertion tool—Used to insert unstripped telephone conductors into the barrel terminations on a distribution interface board

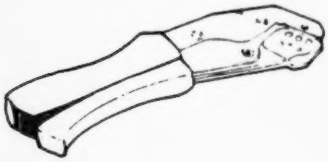


Information Sheet

e. Coaxial cable stripper—Used to strip outer covering from the coaxial cable without damage to the copper center conductor



f. Coaxial cable crimper—Used to terminate coaxial cable with either a male or female F-type connector



SMART HOUSE Wiring
Unit 6

Assignment Sheet 1—Use Article 790 of the *National Electrical Code*® to Answer Questions Related to SMART HOUSE Wiring

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Article 780 of the *NEC* used to answer questions	_____
Accurate and thorough answers	_____
Neat, legible handwriting	_____

Directions: Using Article 780 of the *NEC*, answer the following questions related to SMART HOUSE wiring.

1. Under what three conditions should outlets be de-energized?

2. If a controller malfunctions, can all the associated outlets remain energized?

3. What is the maximum current draw permitted by a signaling circuit?

Assignment Sheet 1

4. Is SMART HOUSE wiring exempt from other articles of the *NEC*?

____

____

5. Can a receptacle used on a closed-loop power distribution system be interchanged with other receptacles?

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